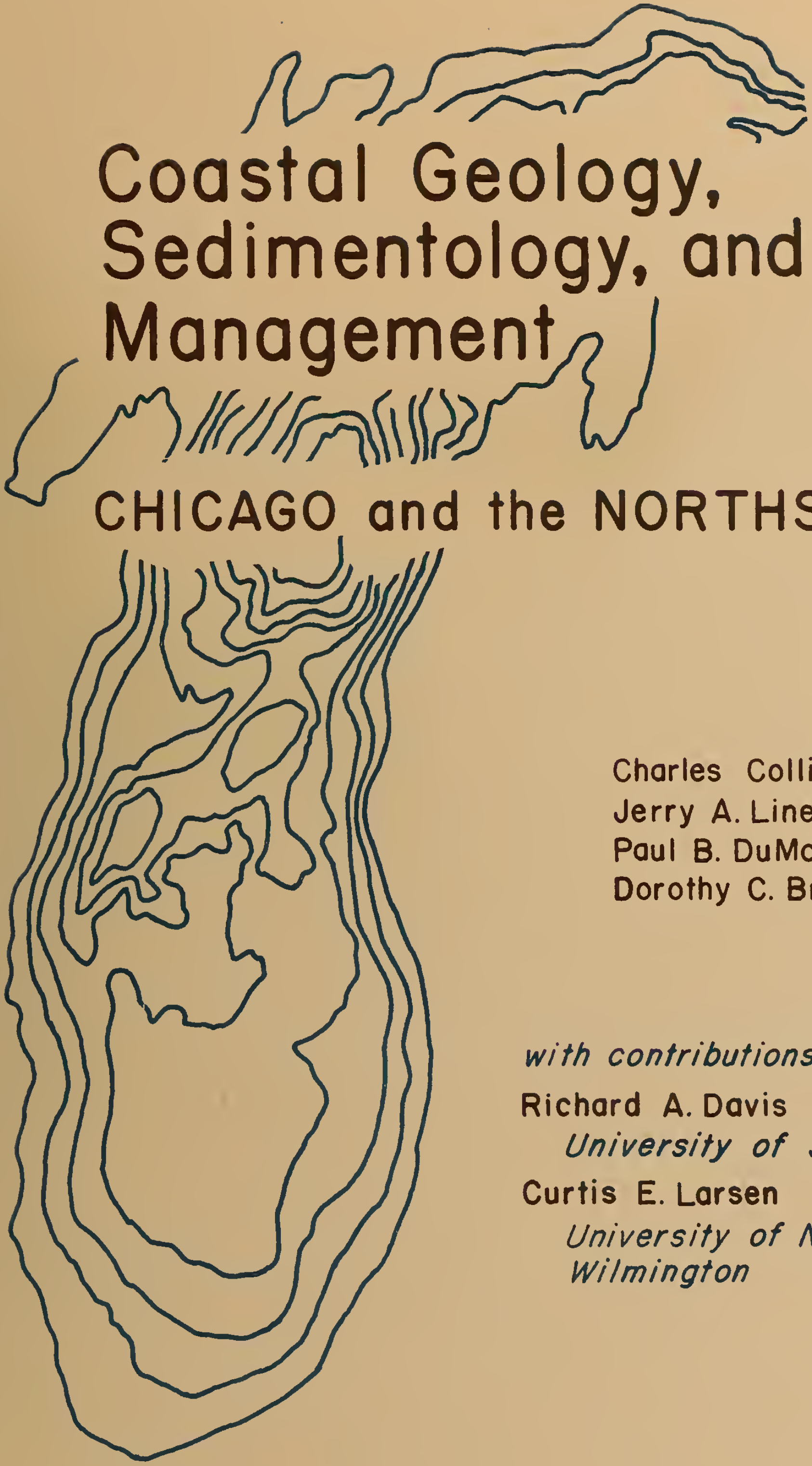

Coastal Geology, Sedimentology, and Management

CHICAGO and the NORTHSHORE

Charles Collinson
Jerry A. Lineback
Paul B. DuMontelle
Dorothy C. Brown

with contributions by

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University of South Florida

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University of North Carolina, Wilmington

Illinois State Geological Survey Guidebook Series 12


ILLINOIS BEACH LODGE
Winthrop Harbor
Zion
173
Wadsworth Rd.
WAUKEGAN
120 Belvidere
North Chicago
U.S. Naval Training Center Great Lakes
Lake Bluff
Lake Forest
Fort Sheridan
Highland Park
Tollway
41
I 294
Glencoe
Winnetka
Wilmette
Tri-State
EVANSTON
I 94
O'Hare
194
Sheridan Road
Kennedy Exp.
Lake Shore Dr.
CHICAGO
Navy Pier
Burnham Harbor
I 294
55
Stevenson Exp.
Jackson Park
LAKE MICHIGAN
N
0 5 10
I 57
I 94
East Chicago
I 80
I 57

GUIDEBOOK SERIES 12

Illinois State Geological Survey

Coastal Geology, Sedimentology, and Management Chicago and the Northshore

CHARLES COLLINSON

JERRY LINEBACK

PAUL B. DuMONTELLE

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Illinois State Geological Survey

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prepared for the 4th Annual Field Conference

GREAT LAKES SECTION

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

September 21 – 22, 1974

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COASTAL GEOLOGY, SEDIMENTOLOGY, AND MANAGEMENT
CHICAGO AND THE NORTHSHORE

INTRODUCTION

Since 1964, when the water level of Lake Michigan-Huron reached an all-time record low of 575.86 feet above sea level, the waters of these lakes have risen through seasonal cycles to a monthly mean level of 580.8 feet in the summer of 1973 and 580.9 feet in the summer of 1974 (fig. 1). These high water levels were accompanied by serious storm episodes. In November 1972 and April 1973, high waves removed thousands of cubic yards of material from the lake shore; endangered houses, public buildings, and industrial works; and flooded underground garages, lower floors of high-rise buildings, nearshore highways, and lowlands. Repairs to sea walls, groins, and sidewalks were costly; in addition, protective measures using riprap, sand bags, sediment-filled barrels and tubes, and new concrete and steel structures involved millions of dollars.

Although earlier shore studies had lapsed in 1962 from lack of funds, public action was not long in coming. In the spring of 1973, the Winnetka Conference (sponsored by civic-minded private citizens) emphasized the need for an emergency conference of local, state, and federal agencies to deal with shore recession and flooding at Illinois Beach State Park and lands to the north. The Lake Michigan Federation, based in Chicago, was the moving force behind the 1973 Lake Michigan Shoreland Conference held at the Field Museum of Natural History. Almost simultaneously, the City of Chicago's Department of Development and Planning produced The Lakefront Plan of Chicago, which was designed to provide shore protection, to create new cultural and recreational facilities, and to preserve and enhance the beauty of the shore.

Late in 1973, the Illinois House of Representatives established the special Committee on Lake Michigan, which has held frequent hearings to establish recommendations for lake and shore management. Shortly thereafter, the mayors of 14 Northshore municipalities organized the Lake Michigan Shoreline Advisory Committee for the purpose of coordinating the planning and action of the various agencies.

The Illinois Department of Conservation and the Department of Transportation (Division of Waterways), in cooperation with the Illinois State Geological Survey and the Northeastern Illinois Planning Commission, began a study program to produce a comprehensive plan of coastal management for Illinois. During the spring of 1974, the State of Illinois applied for funds from the National Oceanic and Atmospheric Administration, Office of Coastal Management. The Federal Coastal Zone Management Act of 1972 offers federal assistance,

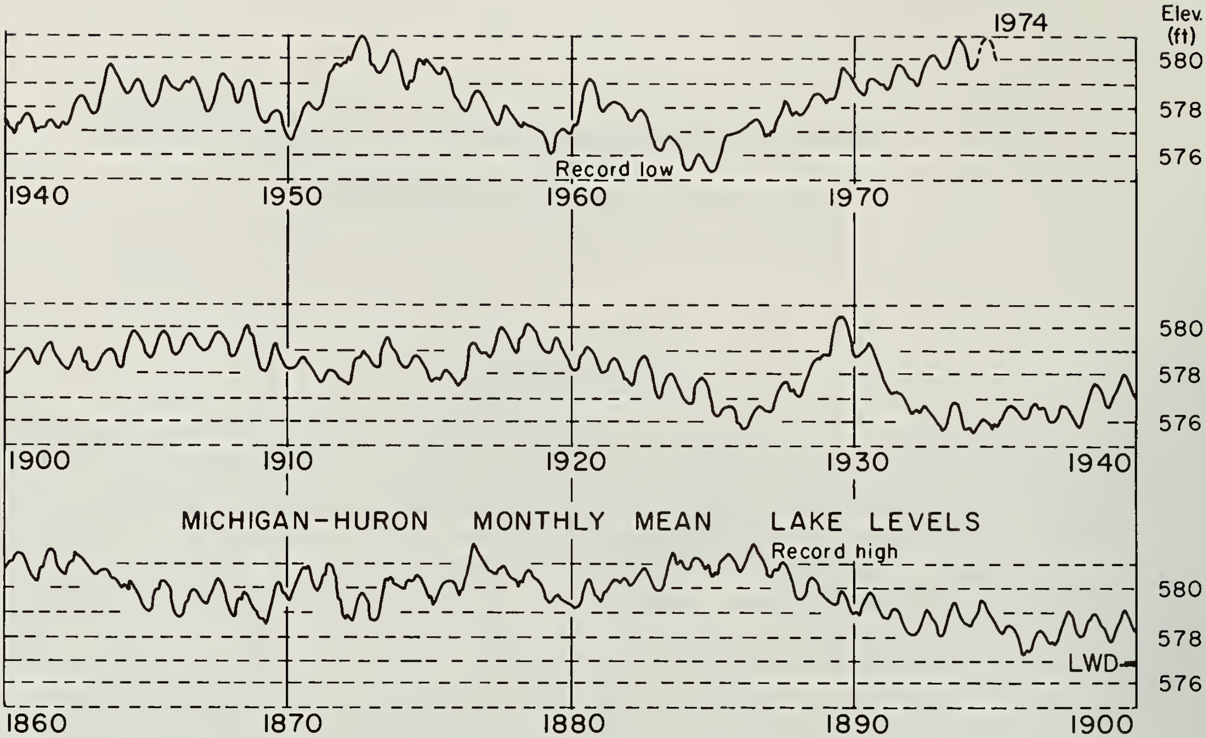


Fig. 1 - Monthly mean levels (feet above sea level) of Lake Michigan-Huron. (After NOAA, National Ocean Survey, Lake Survey Center, Detroit.)

up to two-thirds of the cost, for the development of state coastal management programs. In June 1974, the Geological Survey received support from the Illinois Division of Waterways for the geological study of the shore and nearshore area. In July 1974, further support was received under the sponsorship of the 1972 Act; the Survey was assigned the task of gathering the physical data necessary for developing a coastal management program.

Since 1969, the Geological Survey had carried on a modest coastal study program of the Zion Beach Ridge Complex, a low, ridged, sand plain between Waukegan and Kenosha. In 1973, upon advice from other agencies, the Survey extended the study to include the till bluffs south to Evanston. The program involved the mapping of bottom hydrography and sediment distribution and the measurement of shore recession rates. With the evolution of a formal state program, activities have been expanded to include the topographic and hydrographic mapping of the entire shore and nearshore, the determination of sediment distribution and littoral sediment drift budgets, the study of the effect of storm waves and other such phenomena on the distribution of sediments and shore erosion, the stratigraphy and engineering properties of the shore, the history of the shore and the estimation of its future, and the collection of a comprehensive archive of data related to Lake Michigan and its shore.

The coastal study program has much data to build on. Beginning in 1946, the Illinois Division of Waterways and the U.S. Corps of Engineers undertook the study of beach erosion on the Illinois shore. Subsequently, the Division of Waterways made observations of lake levels, wave heights,

refraction, and periods of wind duration and velocity. In addition, surveys were made of nearshore, shoreline, beach, and bottom sediments. The aerial photographs that were taken of the shore between Evanston and the Wisconsin line have been especially useful. Unfortunately, nearly all such studies ended in 1962 when funds were no longer available. Consequently, 10 years of records that would have included the record low-water level of the lake and the spectacular 1964 to 1974 rise in lake level were never made. It is hoped that the present programs will codify and assure a continuous study and management program for the future.

GEOLOGICAL SETTING

Geologically, the entire shore of Lake Michigan in Illinois is very young. It is generally underlain by the Wadsworth Till Member of the Wedron Formation of Woodfordian age (about 13,000 radiocarbon years B.P.). The Wadsworth, in turn, lies on bedrock dolomite of Niagaran (middle Silurian) age. The Wadsworth is the material of the Zion City Moraine, which forms the 50-foot bluffs at Waukegan, and of the Highland Park Moraine, which forms the 55- to 75-foot bluffs between Winnetka and Lake Forest. South of Winnetka, the shore is covered by shallow-water, nearshore lake sediments in the form of stranded beaches, bars, spits, and deltas that were deposited in ancestral Lake Chicago during the Glenwood (640 ft elev.), Calumet (620 ft elev.), Toleston (605 ft elev.), Nipissing (600 ft elev.), and Algoma (595 ft elev.) lake stages (fig. 2). In a few areas, such as those near the mouths of the Chicago and the Calumet Rivers and in the vicinity of Loyola Park on the far north side of Chicago, laminated silts deposited in still waters (Carmi Member of the Equality Formation) have been recorded. Where these ancient lake sediments are found, the shore is not far above lake level. Most of the shore is between 585 and 590 feet in elevation, well within reach of storm surges and severe seiches during high lake levels.

North of Waukegan, the shore is fronted by the Zion Beach Ridge Complex described by Hester and Fraser (1973) and Fraser and Hester (1974). The complex, which is the main subject of much of the field trip, is a low sand plain, little more than a mile wide, which extends from Waukegan to Kenosha some 14 miles to the north. The area is very young, about 3500 years old at the north end and still being actively deposited today at the south end. Virtually all features seen in the area will be of latest Wisconsinan or of Holocene age.

ACKNOWLEDGMENTS

We are indebted to many people. Charlene Anchor drafted most of the illustrations and typed part of the text in addition to doing field work for the project. Mary Collinson typed part of the text. Mildred Newhouse typed the manuscript and coordinated the project. Phyllis Picklesimer typed the final version. Richard Olson piloted the plane from which most of the aerial photos were made. Kip Mecum, Richard Berg, and Rod Norby did much of the

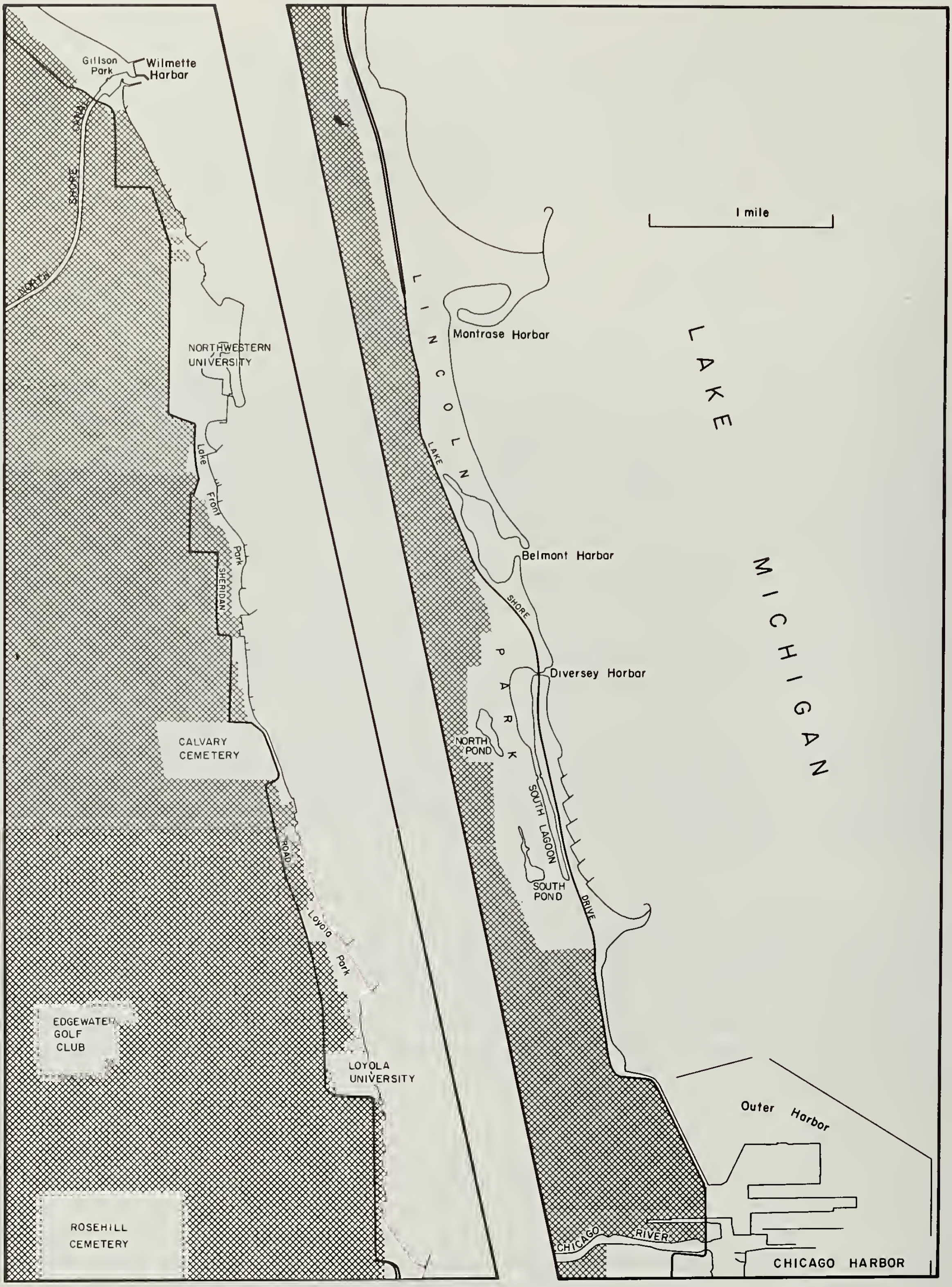


Fig. 2 - Map of lakeshore to be observed from M. V. TRINIDAD. Map taken from USGS Chicago Loop and Evanston Quadrangles (7½ minute, revised 1972).

field work and performed many other duties. Karen Mecum, Robbie Berg, and Katherine Olson helped with field trip arrangements.

Ranger Robert Needham of Illinois Beach State Park and Department of Conservation District Land Manager John Comerio have been helpful in many ways. The Village of Lake Bluff and the Lake Bluff Park District have freely given access to their lands along the shore and greatly expedited our studies. We are also grateful to the Johns-Manville Products Corporation and their Community Relations Representative, Roy F. Winkworth, for their consideration. In addition, we thank George Travers of Commonwealth-Edison Company for up-to-date information concerning the Zion Nuclear Generation Station.

ROAD LOG

CHICAGO RIVER TO NORTHSHORE AND RETURN

ABOARD THE M.V. TRINIDAD

SATURDAY, SEPTEMBER 21, 1974

LEADERS: Charles Collinson, Jerry A. Lineback, Paul B. DuMontelle, Curtis E. Larsen, Dorothy C. Brown

MEETING PLACE: south side of Chicago River, Wacker Drive at La Salle, across the river from and two blocks west of Marina City (fig. 3). The M. V. TRINIDAD will leave the dock at 10 a.m. Parking is available in the general area of the dock. Some free parking can be found on the lower level below Wacker Drive (South Water Street) opposite the TRINIDAD's dock. A city parking building is located on the north side of the river on La Salle Street, and private lots are located on the south side of Wacker Drive between Clark and Wabash. Other lots are available under Michigan Boulevard on the north side of the river. The TRINIDAD's dock may be reached from I-94 exit on Ohio Street—take Ohio to La Salle, turn right, and proceed seven blocks to Wacker, which borders the Chicago River. The dock can also be reached from Lake Shore Drive (U.S. Route 41) via Jackson, Monroe, or Randolph Streets by going westward to La Salle, then north to Wacker.

At 10 a.m., the TRINIDAD will sail on the Chicago River past Marina City, the Sun-Times Building, the Wrigley Building, and the Tribune Tower—all on the north bank. After the TRINIDAD passes under Michigan Boulevard, the white Standard Oil Company Building can be seen due south. The Sears Building, the tallest building in the world, is west of the Loop and can best be seen from the lake. The John Hancock Building, which dominated the skyline for a few years, is located nearly a mile due north. The Chicago River formerly flowed eastward directly into the lake (fig. 2), but in the 1860s the Illinois and Michigan Canal was dredged, and locks were built at the mouth of the river to divert the flow westward and carry away the sewage of the city.

The Chicago lakefront has been the city's pride for over 100 years and the city is now committed to the long-term "Lakefront Plan of Chicago," wherein the shore will be developed as a multi-use archipelago of artificial islands built from more than 67 million cubic yards of stone to be taken from underground development programs—the expansion of the subway and the Metropolitan Sanitary District's "Project Underflow" tunnels. The plan is a reaffirmation and enhancement of the Daniel Burnham plan of 1909, which called for "beaches, lagoons, islands, harbors, and cultural facilities." The Lakefront Plan of 1973 calls for 1055 to 1390 new acres of islands and shore, 10 miles of new beaches, 9 new launching ramps, spaces for 5000 boats, a stable, and 6000 acres of protected waters. Displays detailing the plan are available aboard the TRINIDAD.

From publications of State and Government surveys by Leverett, Alden, Blatchley, Lane, Atwood, Goldthwait, and others
Compiled by V. E. Shelford. Published by the Geographic Society of Chicago
(CIRCA 1912-13)

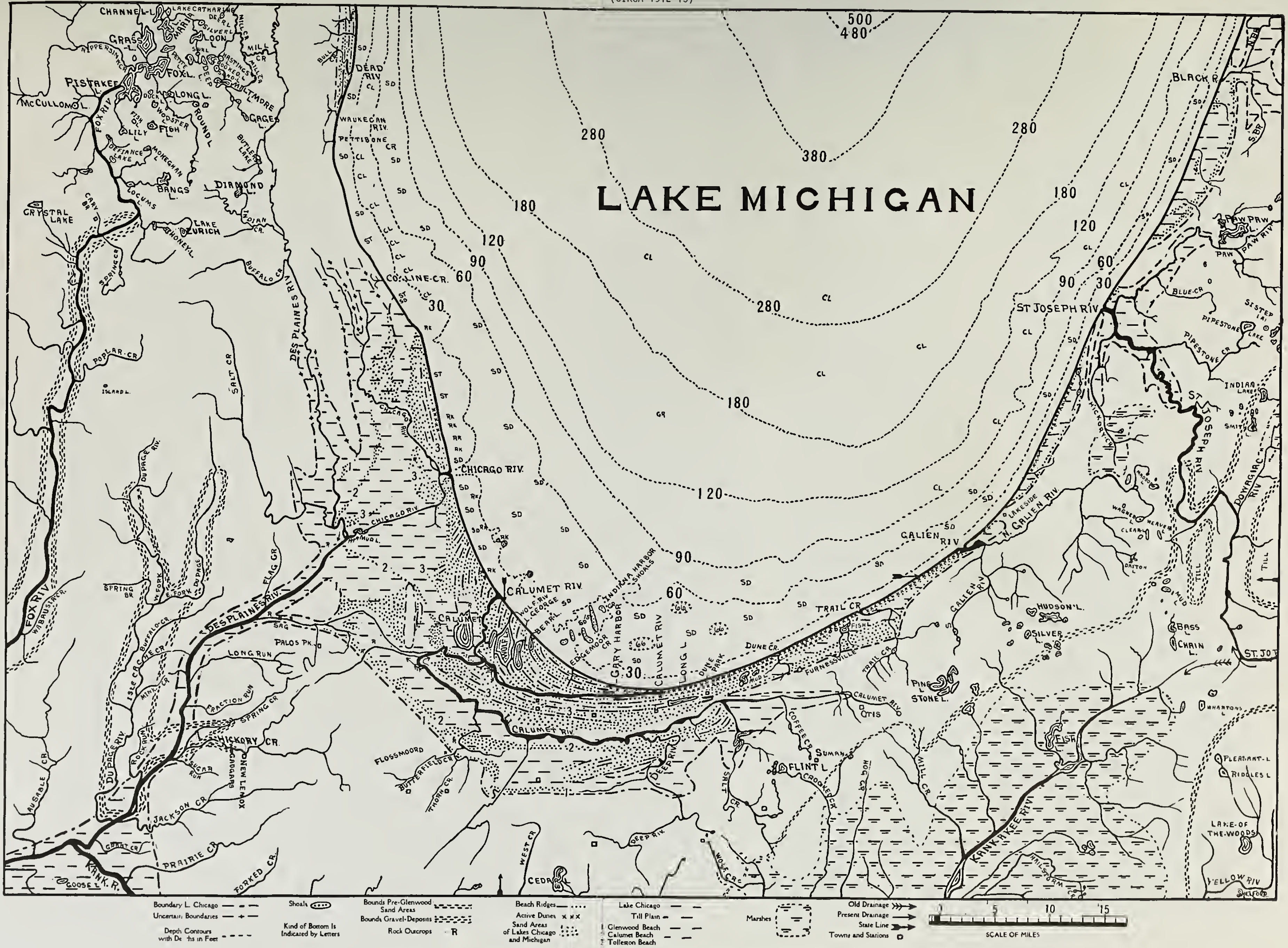


Fig. 3 - Ecological base map of the Chicago area.

After leaving the locks, the TRINIDAD will traverse the Outer Harbor where the spectacular Chicago skyline can be seen to its fullest advantage. Northward toward the "Gold Coast" are sites where high water and storm-driven waves have posed serious physical and legal problems. Some arise from wave concentration due to reflection. We shall pass Oak Street Beach, North Avenue Beach, Montrose-Wilson Beach, and others—all of which have their own characteristics. We shall pass Calvary Cemetery, where Sheridan Road is involved in a contest with the lake, and we shall examine the Northwestern University landfill, which may or may not interrupt the southward flow of littoral sand. Farther north, beyond Wilmette, we shall encounter the bluffs of the Northshore and discuss both erosion and governmental problems involved with managing the bluffs and restoring the beaches.

Sack lunches will be served at noon. For those who skipped breakfast, coffee and doughnuts will be available aboard.

The general geology of the lake's southern basin, the lake circulation patterns, and the sediment distribution in the basin will be discussed on the return trip. After returning to the dock in early afternoon, please take personal transportation to Illinois Beach State Park at Zion, the field trip headquarters, 45 miles to the north. Suggested routes give a choice between rapid travel and scenic drives.

Upon arrival at Illinois Beach State Park Lodge in late afternoon, several beach displays will be available, as well as demonstrations of the park's Littoral Environment Observation (LEO) Station. Those who wish may hike southward into the Nature Preserve part of the park—the last natural shore in the State of Illinois—where one of the few examples of high-water beach accretion can be observed. If possible, boats and cars will be available for transport into the preserve. If waves are high, the Survey storm-wave sled will be demonstrated.

SATURDAY EVENING—Happy Hour, Banquet, Business Meeting, and Lectures on Lake Michigan Shore Studies.

ROAD LOG

ILLINOIS BEACH STATE PARK
TO LAKE BLUFF AND RETURN

SUNDAY, SEPTEMBER 22, 1974

LEADERS: Charles Collinson, Jerry A. Lineback, Paul B. DuMontelle, Curtis E. Larsen, Dorothy C. Brown, and Leon R. Follmer.

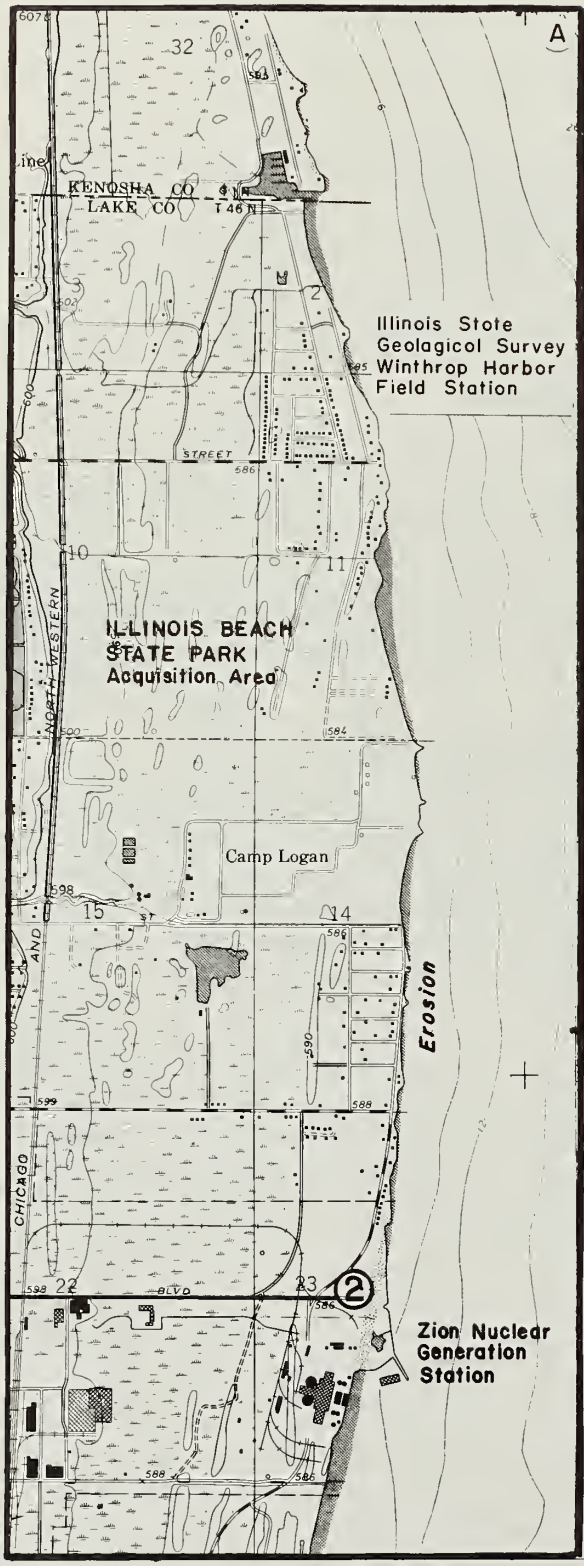
Meet in parking lot at Main Beach 3/4 mile north of Illinois Beach Lodge. Cars may be left in the parking lot. STOP 1 will be near the parking lot so late arrivals may join the group there. See figures 4A-D for route maps.

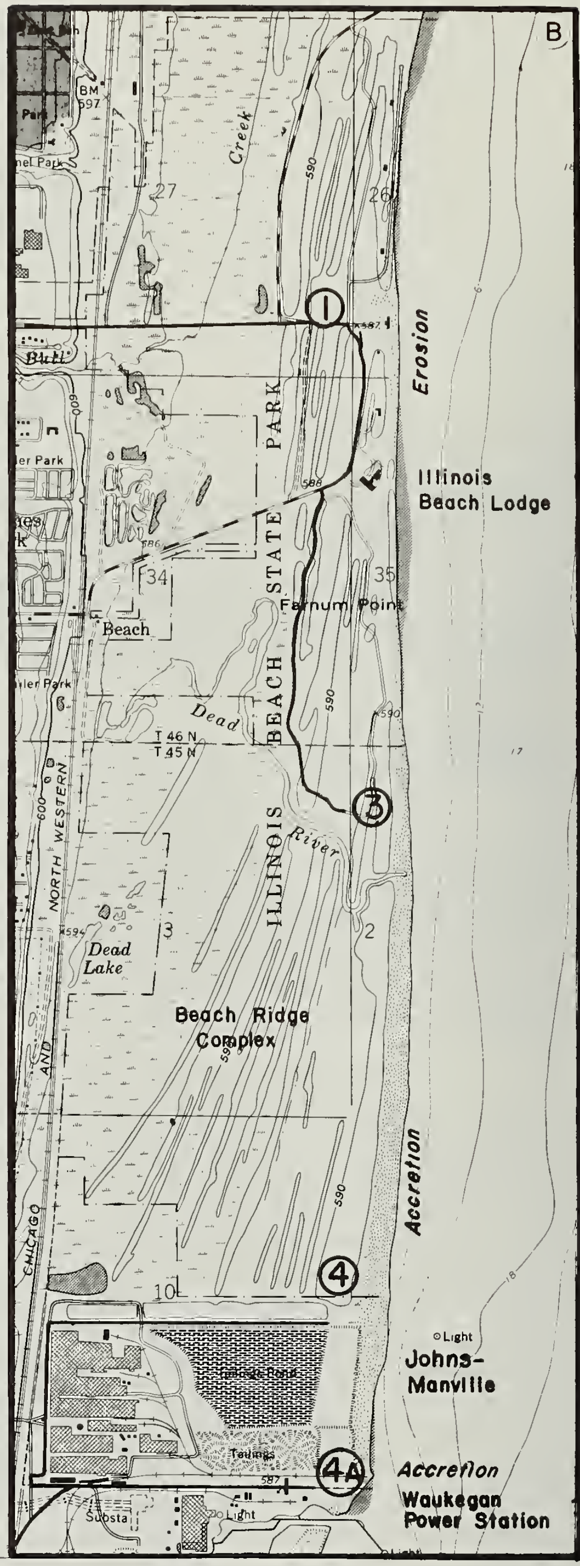
STOP NO. 1 ILLINOIS BEACH STATE PARK, MAIN BEACH. E½ SE¼ Sec. 27, T. 46 N., R. 12 E., Zion Quadrangle.

The main bathhouse on this beach, Illinois Beach Lodge, and the three bathhouses to the north were the subject of a hastily convened conference in April 1973. High water and strong winds from the northeast had removed hundreds of cubic yards of sand in a matter of hours from what were already seriously eroded beaches (table 1 and fig. 5). The service road was cut and much of the park was flooded including the lower levels of the Lodge, the roadways, and the parking lots.

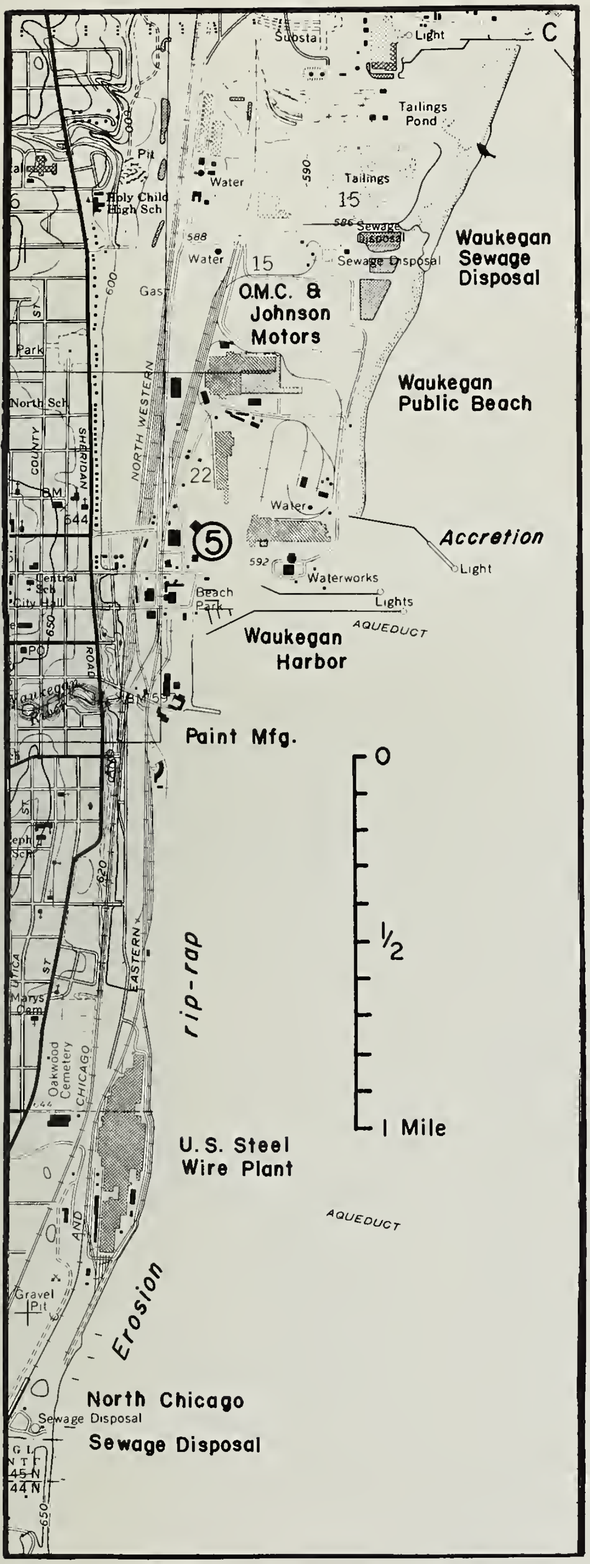
The first serious erosion due to the present high water cycle occurred at the north end of the park, just south of the Zion Nuclear Generation Station site, not long after a safe harbor jetty was built for construction purposes. As first damage occurred, the reactor builders responded with the construction of a steel bulkhead and the placement of riprap as well as sand fill. At first, the materials were placed only at the site of erosion but, as that portion of the shore was armored, erosion moved downdrift (southward). Consequently, riprap now extends as far as this main beach (pl. 1). As the material was eroded by storms, sediment moved down the shore as slugs of material manifested by migratory prominences. Plate 1 shows the main beach and bathhouse in 1971 and 1973, after two severe seasons of storms. In winter 1974, the 30-year old flagpole was undermined along with the main bathhouse which was subsequently removed. Recently, the beach was refurbished by the addition of 25,000 cubic yards of sand to cover debris and to provide resources for the coming winter months. If the beach is further cut away by severe storms, the material will supply littoral drift sediment southward (downdrift) where the Lodge, the one structure the park cannot afford to lose, is located.

The sand dike at the back of the beaches is to reduce flooding due to wave run-up which measures seven to eight feet in height in this area.





Figs. 4A to D - Field conference route maps showing numbered stops. The maps are modified from USGS Zion and Waukegan Quadrangles (7½ minutes, revised 1972).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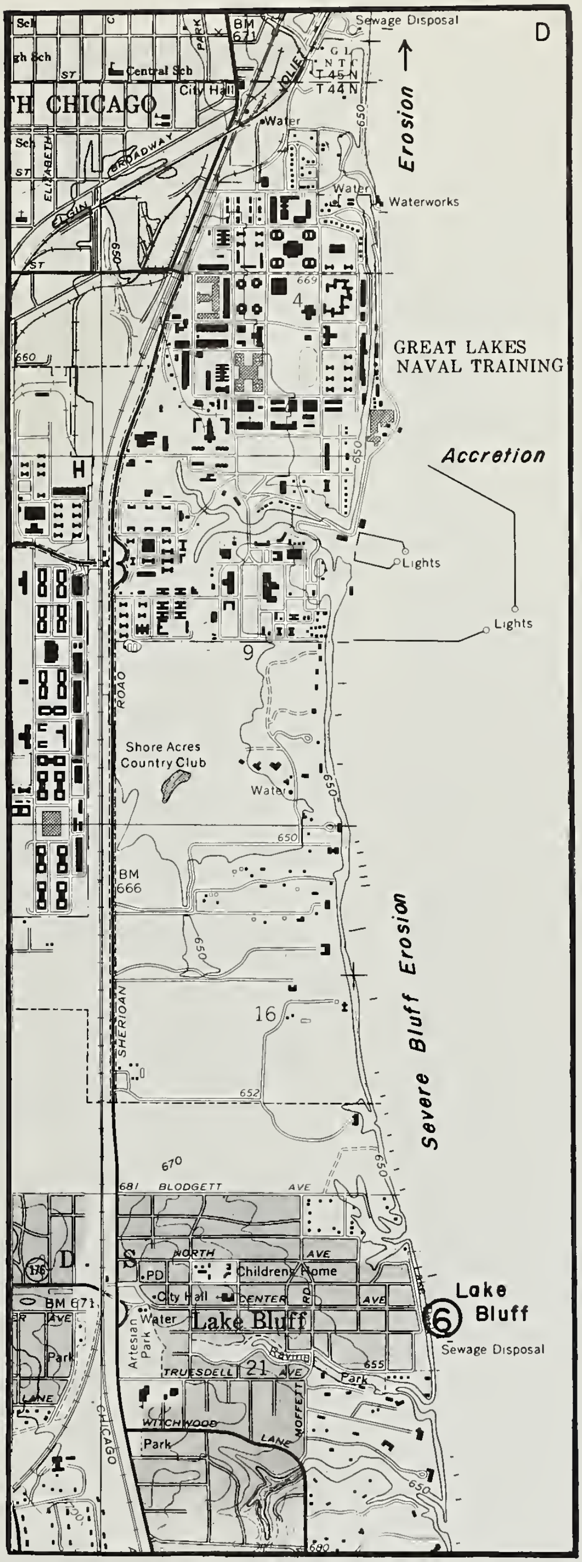
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BLODGETT
AVE
NORTH
AVE
Childrens Home
City Hall
CENTER
Lake Bluff
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Artesian Park
TRUESDELL
Park
WITCHWOOD
Park
Lake
Bluff
6
Sewage Disposal
CHICAGO

TABLE 1—SHORE LOSS OR GAIN BETWEEN 17TH STREET, ZION, AND JOHNS-MANVILLE, 1969-1973

Date of shoreline	June 11 1970		Sept. 8 1971		May 22 1972		April 27 1973		May 11 1973	
Shoreline shift in feet since— (italics show cumulative total)	Apr. 1969	June 1970	Apr. 1969	June 1970	Apr. 1969	Sept. 1971	Apr. 1969	May 1972	Apr. 1969	May 1973
Lake level (Harbor Beach, MI)	579.6	579.25	579.6	579.25	579.6	579.7	579.6	579.6	579.6	579.9
Position of lake level in annual cycle	Rise Med.	Rise Med.	Rise Med.	Rise High	Rise Med.	Fall High	Rise Med.	Rise Med.	Rise Med.	Rise High
Jetty installed								Jetty removed		
17th Street, Zion	--	--				+19			*- 13*	-32
Wilson Court	--	--				+ 9			*- 12*	-21
21st Street, Zion	--	--				- 3			*- 27*	-24
1550 ft south of 21st Street	*- 11*	--	*- 41*	-30	*-53*	-12	--	--	*-165*	-112
Pump House, 2500 ft south of 21st St.	*+ 30*	--	*+ 78*	+48	*+47*	-31	--	--	*- 5*	- 52
Jetty location										
Bathhouse #1, Illinois Beach St. Pk.	*-103*	--	*-182*	-79	--	--	*-193*	- 11	*-179*	+ 14
Bathhouse #2, I.B.S.P.	*-103*	--	*-201*	-98	--	--	*-245*	- 44	*-198*	+ 47
Bathhouse #3, I.B.S.P.	*+ 61*	--	*+ 4*	-57	--	--	*-156*	-160	*-133*	+ 23
Bathhouse #4, I.B.S.P.	*+ 6*	--	*+ 33*	+27	--	--	*- 91*	-124	*- 70*	+ 21
NE Corner Lodge, I.B.S.P.	*+ 2*	--	*- 15*	-17	--	--	*- 35*	- 20	*- 3*	+ 32
NE Corner Tennis Courts, I.B.S.P.	*+ 23*	--	*- 2*	-25	--	--	*- 27*	- 25	*+ 5*	+ 32
850 ft north of mouth of Dead River	*- 11*	--	*- 15*	- 4	--	--	*-110*	- 60	- 72	+ 38
250 ft south of mouth of Dead River	*+ 51*	--	*+ 94*	*+43*	--	--	*+ 52*	- 42	*+ 64*	+ 12
2500 ft south of mouth of Dead River	*+ 17*	--	*+ 83*	+66	--	--	*+ 11*	- 72	*+ 16*	+ 5
3450 ft south of mouth of Dead River	*+ 36*	--	*+134*	+98	--	--	*+ 77*	- 57	*+107*	+ 30
6200 ft south of mouth of Dead River	*+ 10*	--	*+ 32*	+22	--	--	*+142*	+110	*+157*	+ 15

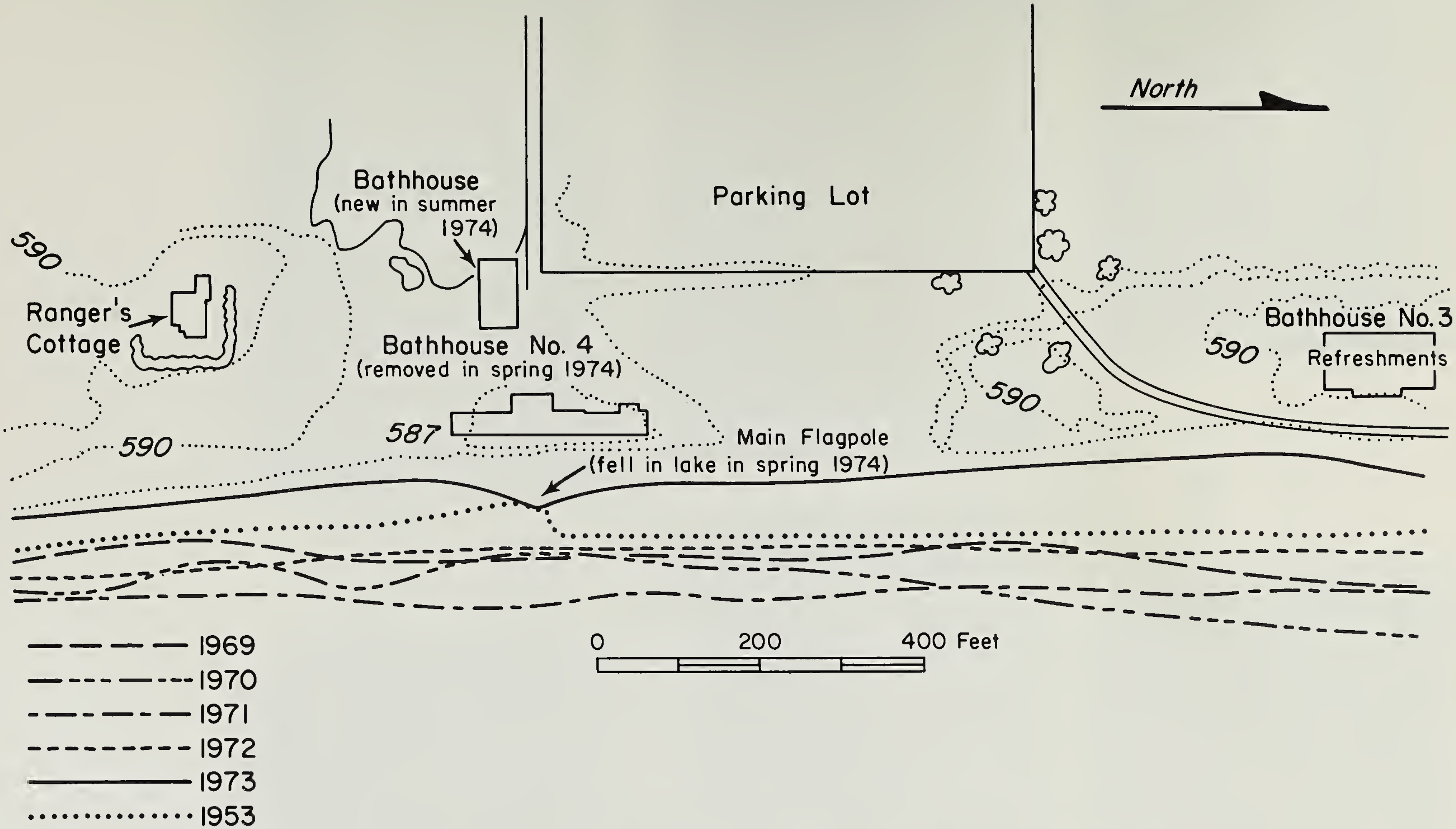

Fig. 5 - Vicinity of Main Beach Parking Lot near former location of Bathhouse No. 4 showing position of shoreline since 1969. The 1953 shore is also shown to illustrate the fact that, although water levels were higher in 1953, damage was greater in 1973. Shoreline for 1974 is not shown.

PLATE 1

A. Emergency riprap groins and sand fill near northern bath-houses in Illinois Beach State Park in October 1971. Later, higher water levels and storms required further additions of riprap and fill.

B. Shore erosion north of southernmost concrete bathhouse (No. 3) showing advance of erosion in front of advancing riprap wall in background. In April 1973, 140 feet of recession occurred at this place during a single storm episode.

C. Houses located just north of the Zion Nuclear Generation Station. In 1972 these were protected by a hundred feet of grassy lawns, trees, and patios. This picture was taken in July 1973. In 1974, they were entirely undermined and subsequently demolished.

D. House located on Lakefront Drive in Zion. The house was protected by many cubic yards of concrete but was outflanked by waves running up as much as 8 feet above lake level in April 1973.

E. The main beach at Illinois Beach State Park in October 1971. The beach was especially wide because of the addition of material eroded by drift in the northern part of the park.

F. The main beach at Illinois Beach State Park in January 1974. Almost 150 feet of recession had occurred since 1971. The rocks and posts in the left foreground mark the 1951-53 high water levels and were covered and forgotten for 20 years. The flag pole and main bathhouse were undermined during spring 1974.

PLATE 1

Mileage

00.00	00.00	Leave Main Beach Parking Lot. Turn west on entrance road past trailer camping area and cattail marsh. In the marsh to the right, cores containing peat were dated at 715 ± 75 radiocarbon years B.P. and 540 ± 75 radiocarbon years B.P. Eventually, such dates will permit the reconstruction of a precisely detailed history of the sand plain.
00.95	00.95	Chicago and Northwestern R.R. tracks.
01.10	02.05	STOP LIGHT. Intersection of Wadsworth and Sheridan Roads. Turn right (north) into Zion.
01.45	03.50	STOP LIGHT. Zion is a town with a religious heritage. It is experiencing substantial growth at present partly due to the location of the Zion Nuclear Generation Station here.
01.95	05.45	STOP LIGHT. Cemetery on right.
02.20	07.65	STOP LIGHT. This is the main business district. Although small, Zion prides itself on handsome parks, a modern library, swimming pools, and an ice rink. The town was founded in 1900 by a religious group led by the Reverend John Alexander Dowie. Rev. Dowie was the founder of the Christian Catholic Church (a Protestant sect) which surveyed and planned the entire town of 6400 acres before a single building was built. The large, block-long Zion Hotel (originally named the Elija Hospice) on the right was built in 1901 for housing the workmen who came to build the town. Later it was used to house the faithful who made pilgrimages here. It has 300 rooms with dining facilities for 1000. The large red brick houses along Shiloh Boulevard were built for the leaders of the sect. Street names like "Galilee," "Emmaus," and "Ezekiel" clearly show the town's heritage. The Zion Passion Play, still performed regularly during summer months, draws visitors from great distances.
02.43	10.08	STOP LIGHT. Intersection of Shiloh Road and Sheridan Boulevard. Turn right and proceed eastward. The land ahead is a natural marsh and bog area which is commonly flooded by heavy rain and by storm surges from the lake.
02.80	12.88	R.R. tracks and power lines on left.
03.50	16.38	R.R. tracks. Continue eastward; STOP NO. 2.

STOP NO. 2

NORTH SIDE ZION NUCLEAR GENERATION STATION. SW¼ NE¼ Sec. 23, T. 46 N., R. 12 E., Lake County, Zion Quadrangle.

The Zion Nuclear Generation Station (pl. 2) was essentially completed in 1973 by Westinghouse for the Commonwealth Edison Company. The plant, a twin reactor of the boiling water type with a capacity of 2200 Megawatts, is the

largest nuclear generation station in the world. At full capacity, it circulates one billion gallons of cooling water from the lake every 24 hours. Water is taken in through a 2600-foot tunnel buried in the floor of the lake. Two outlets 765 feet apart and 765 feet from the crib house float the heated water out onto the top of the lake water. The excurrent water must be no more than 19.6°F above ambient water temperature. The heated water at each outlet covers 1½ acres at lake bottom and covers 54 acres at the 3°F isobar. Water is at ambient temperature 2000 yards downdrift.

Sediment distribution at the reactor site is being carefully mapped by the Illinois State Geological Survey. The possibility is being considered that heated currents may to some extent affect longshore littoral sediment drift and possibly divert some sand lakeward beyond wave base.

The shore north of the reactor (updrift and essentially unaffected by the reactor) was the site of severe erosion and much damage to dozens of residences, streets, and highways during fall and spring storms of 1972-73 (pl. 3). Many residents were originally displaced by the nuclear plant and were greatly discouraged when high water drove them from new home sites. Numerous washover deltas attest to the severity of the 1973 storms. The State of Illinois is now acquiring the land for addition to Illinois Beach State Park and has forbidden the construction of permanent buildings in the shore zone.

<u>Mileage</u>

	16.38	Leave STOP NO. 2 and return westward to Sheridan Road.
09.82	26.20	STOP LIGHT. Shiloh Boulevard and Sheridan Road. Turn left (south), returning past the intersection of Wadsworth Road and Sheridan Road. Note the absence of liquor stores in Zion proper.
08.03	34.23	STOP LIGHT. Wadsworth Road. Turn left (east) to STOP SIGN at main beach parking lot in Illinois Beach State Park.
01.90	36.13	STOP SIGN at main beach. Turn right on Beach Lodge Road.
00.40	36.53	Lodge on left.
00.10	36.63	Turn left toward Nature Area and continue straight ahead through parking lot to gate.
00.10	36.73	Enter gate to Nature Preserve. This area is reserved for hiking. Groups must have special permission to enter. During summer the Park Naturalist conducts nature hikes on a daily basis.
00.95	37.68	Follow gravel road through Nature Preserve curving around to the left until road turns north. Buses will turn around here. Walk east to lake shore through break in ridges. Then turn south to mouth of Dead River.

PLATE 2

A. Aerial view of the Zion Beach Ridge Complex as developed in Illinois Beach State Park. The bluff line shows in the lower left. Dead River begins in the upper left and meanders to the upper center. The light line paralleling the shore is the submarine nearshore bar. Illinois Beach Lodge is in the extreme upper left.

B. Inflatable runabout equipped with recording fathometer and short-wave radio. The boat is extremely stable, safe, fast, and portable. It is used for nearshore hydrographic surveying.

C. View lakeward at south end of beach at Illinois Beach State Park. Shore advance is in progress here by means of the building of washover fans and deltas such as the sand and gravel structure in the near background. Windblown sand and silt helps to build the structures into ridges by entrapment around beach grasses.

D. Jetty of the Outer Harbor at Waukegan showing the public beach in the background. The light area of water in the right foreground represents suspended fine sediment. The dark area between it and the jetty consists of pollutants from the shore.

E. Scene near the entrance lock to the Chicago River. A high-rise residential building on the left is well protected from waves by the harbor jetties. The John Hancock building is on the right. The freighter is docked at Navy Pier.

F. 2200 Megawatt nuclear generation station at Zion. The sediment lining the shore in front of the station is littoral drift material in transit past the station.

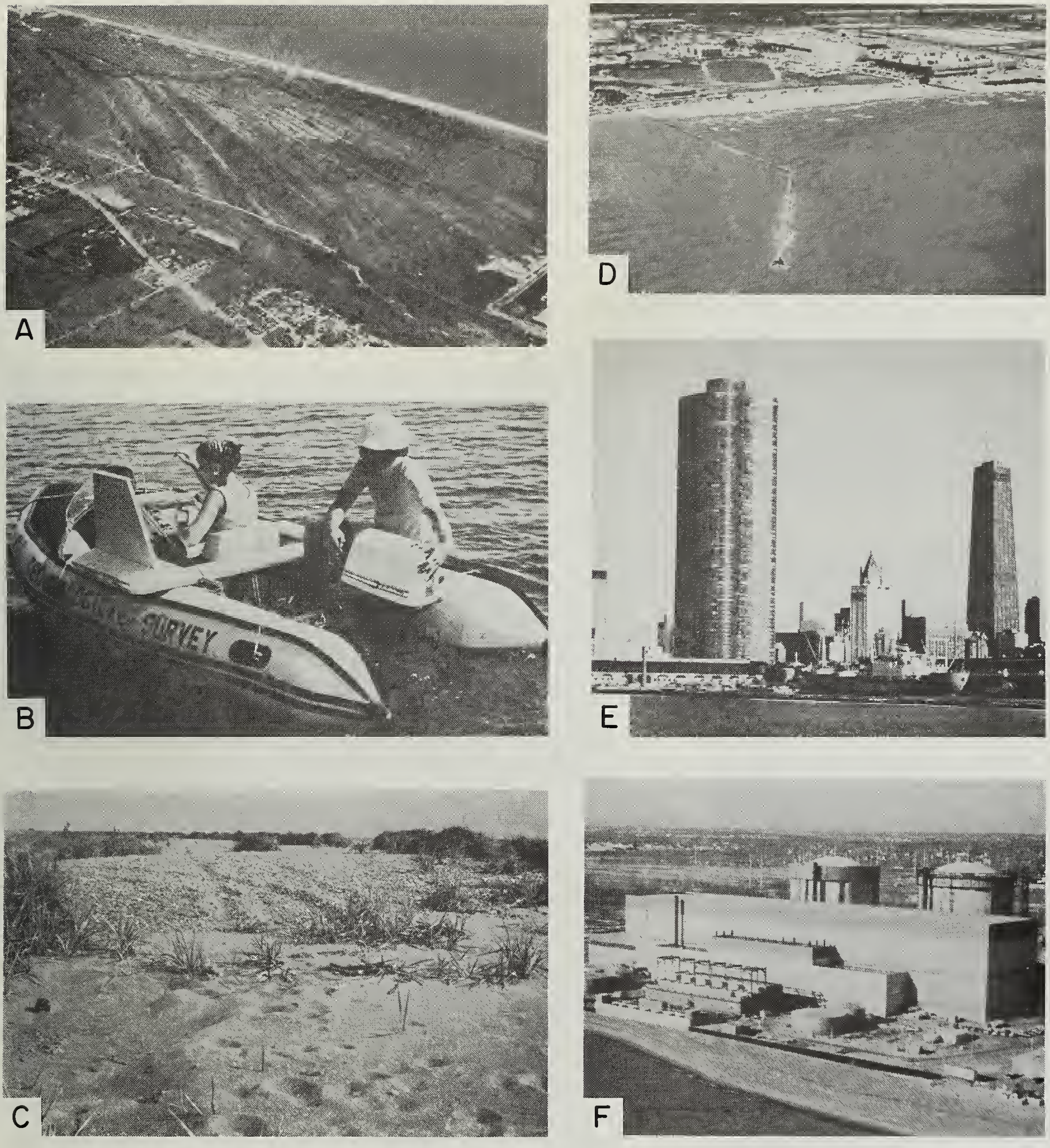

PLATE 2

PLATE 3

A. Severe bluff erosion at Lake Bluff where a sheet piling bulkhead has been left unrepaired. The loss probably represents only 4 years of recession.

B. Wave reflection on the updrift side keeps the groin scoured clean while some sediment remains on the downdrift side.

C. Wedron Till Member, STOP NO. 6, just south of the Lake Bluff Sewage Plant. Note lines of seepage along the top of the bluff.

D. Undercutting of an exposed till bluff causes slumping and rapid transport of the slumped material.

E. Partly-submerged short groins (top) and long, emergent groins give little protection at high water as evidenced by the light-colored patches of water which mark lakeward currents induced by reflected waves.

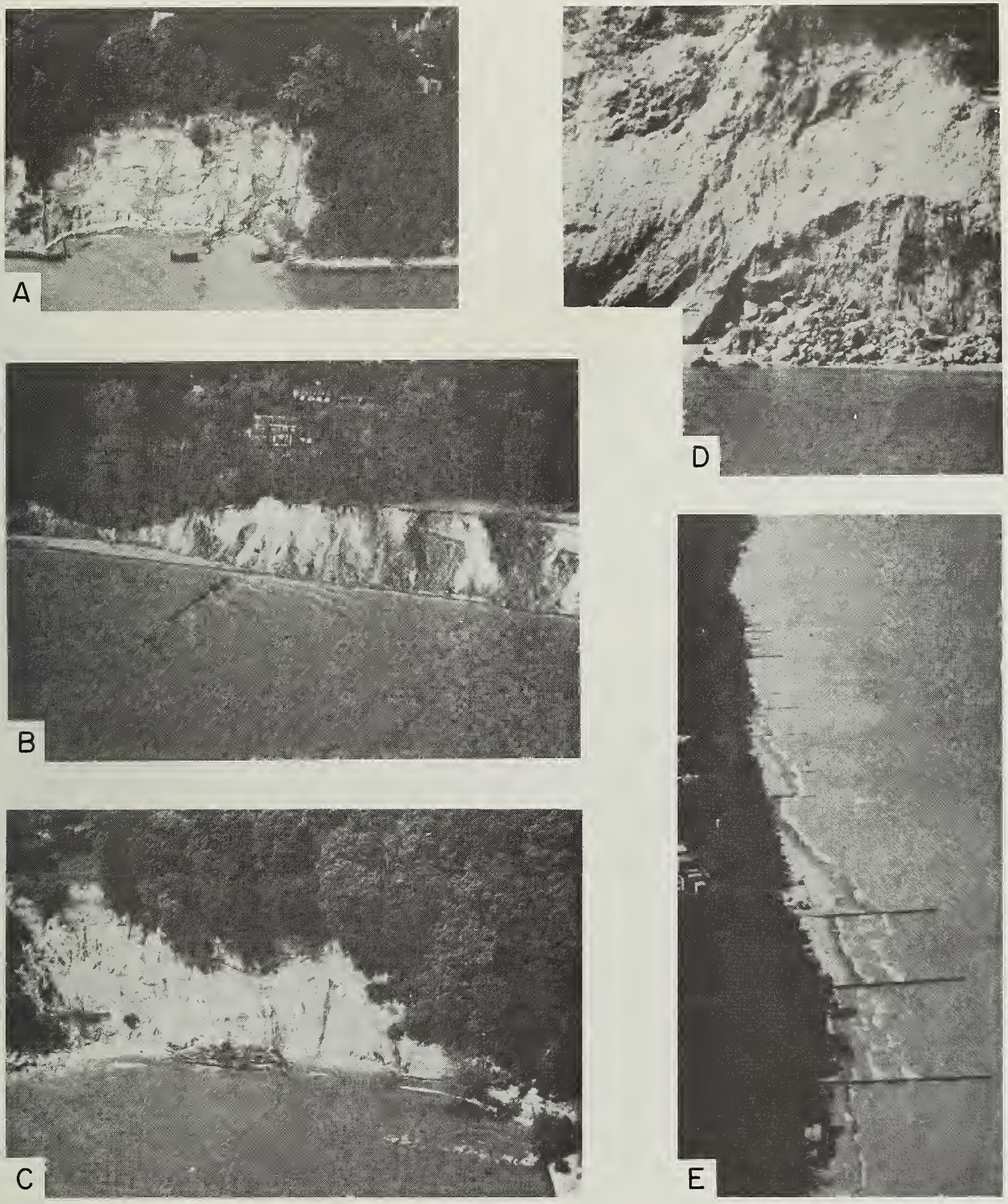

PLATE 3

STOP NO. 3 MOUTH OF DEAD RIVER, ILLINOIS BEACH STATE PARK. NE¼ SE¼ NE¼ Sec. 3, T. 45 N., R. 13 E., Lake County, Zion Quadrangle.

This is a middle location on the last stretch on natural shore left in Illinois—2 miles of Illinois Beach Nature Preserve. Unfortunately, recent storms accompanied by the 1970-74 high water levels have depleted the lakeward tiers of highest dune-ridges. The area is especially valuable to sedimentologists as well as botanists and zoologists because it not only preserves natural beach features, but it also traces the history of the shore ridge-by-ridge. As can be seen from figure 14 in the report by Curt Larsen (p. 50), the ridges we stand on date from the 1800s and earlier, while those southward date up to modern times.

The rush, cattail, and grass marshes that are well developed between the ridges are old enough to have developed peaty zones that are datable by radiocarbon methods. These radiocarbon dates give us an opportunity to interpret past history and to predict the future for the area. The study by R. A. Davis and W. T. Fox (this Guidebook) of the beach, wind, wave, and current area lying just to the north was not very successful because the weather in summer 1974 was exceedingly mild.

Exposed along the beach is a widespread dark paleosol horizon that resembles a heavy mineral concentration. It is essentially modern.

<u>Mileage</u>

	37.68	Leave STOP NO. 3 and return to Beach Road.
00.95	38.63	Junction with Beach Road. Turn left (southwest) and travel to Sheridan Road. We are passing through bogs, estimated by means of radiocarbon dates and archeological remains, to be between 300 and 700 years old.
01.10	39.73	STOP SIGN. Intersection of Beach Road and Sheridan Road. Turn left (south).
00.70	40.43	Yorkhouse Road. Continue ahead. We enter Waukegan (pop. 65,200) at Blanchard Road. Established as a trading post in 1695 and incorporated as the town of "Little Fort" in 1841, the name was changed to the Indian name "Waukegan" in 1859. Waukegan is the Lake County seat—Lake being Illinois' second wealthiest county—and a long-time manufacturing center. Johnson Outboard Motors and Outboard Marine Corporation, manufacturers of inboard/outboard boat motors and Lawn Boy mowers, are located at the waterfront, along with U.S. Gypsum Company. Larsen Marine, also located there, is a well known outfitter of yachts. U.S. Steel has a large wire plant on the south waterfront. Johns-Manville, manufacturer of insulation and pipe products, has been located at the same site for decades.
01.20	41.63	STOP LIGHT. Seventh Street. Continue southward.

Mileage

00.65	42.28	STOP LIGHT. Greenwood Avenue. Turn left proceeding eastward, downhill, toward the lake. Bowen Park is on the left.
00.46	42.74	STOP SIGN. Turn left (north).
00.15	42.89	STOP SIGN. Continue north, entering Johns-Manville manufacturing plant. Proceed to northernmost side of building and turn right (east) toward the lake. Follow plant road past spoil piles to end.

STOP NO. 4 SOUTH BEACH, ILLINOIS BEACH NATURE PRESERVE. West edge, SW¼, Sec. 11, T. 45 N., R. 12 E., Lake County, Zion Quadrangle.

The 2¼-mile stretch of shore north of the Waukegan Power Station pier is the only significant part of the Illinois shore that is advancing toward the lake. More than 50,000 cubic yards have been added since 1970. The rate is related to storm episodes that remove material to the north and move it southward. Most material that travels as far south as the pier is shunted lakeward by the excurrent cooling water of the power plant.

The area illustrates the process by which the beach ridges and dunes grow. High water levels and storm surges cause numerous washover deltas by which sediment deposits up to a few feet deep are left perched above water level. Then, as seasonal winter low water levels occur or as the water level in general falls, very wide beaches of fine sand are exposed to winter onshore winds. Then sand is piled onto the upper beach where it is trapped by vegetation and built into a dune-covered beach ridge. If the water levels were again to fall to the record low level of 1964, a beach several hundred feet wide would be exposed along this shore at this location.

Mileage

	42.89	Leave STOP NO. 4 and return to Main Gate.
01.30	44.19	Main Gate. Turn left (south) over overpass on blacktop road paralleling the Chicago & Northwestern R.R. tracks.
00.15	44.34	STOP SIGN at top of overpass. Continue straight ahead.
00.15	44.49	Entrance road to Commonwealth-Edison Waukegan Fossil Fuel Generating Plant on left. Alternate STOP NO. 4A is at the lakeward end of this road.
00.05	44.54	Jenkins-Boller plant entrance on left.
00.04	44.58	Johnson Motors Marine Service School Plant No. 3 on left.
00.35	44.93	STOP SIGN at top of overpass—junction with Mathon Boulevard. Proceed straight ahead. The U.S. Gypsum Company dock can be seen to the left.

Mileage

00.10	45.03	Four-hundred-foot bulk carriers dock here. STOP SIGN. Turn left (east). Large ship's propellor on corner near Mathon's Restaurant which specializes in fine fish.
00.10	45.13	Turn right into parking spaces opposite the Waukegan Yacht Club for STOP NO. 5. Coffee and harbor gawking.

STOP NO. 5 ATKINSON'S BOATHOUSE, WAUKEGAN HARBOR. SW¼ NW¼ Sec. 22, T. 45 N., R. 12 E., Lake County, Waukegan Quadrangle. Coffee and doughnuts in the park.

Waukegan Harbor is the only public harbor between Wilmette, 20 miles to the south, and Kenosha, 15 miles to the north. The harbor dates from the turn of the century and in recent years has become severely crowded.

The harbor jetties are important sedimentologically, as well as from a coastal management point of view, inasmuch as southward migrating littoral sediments are trapped and/or diverted lakeward by the jetties so that the harbor mouth must be dredged periodically to maintain navigation depths. Approximately 70,000 cubic yards of sand were dredged during summer 1974 and stockpiled near the Johnson Outboard Motors plant. Such dredgings are very useful in estimating annual sediment budgets.

Apparently little sediment bypasses the Waukegan area as manifested by the paucity of sandy sediments on the nearshore lake floor for some distance south of Waukegan.

The shore between the Waukegan Power Plant pier and Waukegan Harbor is relatively stable with enough sediment bypassing the power plant pier to maintain broad low-slope beaches and nearshore shallows. At the same time, the Waukegan Outer Harbor jetty effectively retains the material.

The harbor has a long history as a commercial fishing port and, although the industry in essence died out for a period of nearly 30 years, the demise of the lamprey and the advent of salmonid and trout stocking have revived commercial fishing and given rise to a flourishing sport fishing industry as well.

Mileage

	45.13	Leave STOP NO. 5 going south on Harbor Place Road.
00.08	45.21	STOP SIGN. Turn right (west). Ramps for trailered boats lie directly ahead. The recent advent of salmon and lake trout fishing leads to great congestion at times. In addition, fleets of sailboats have been added in recent years.
00.02	45.23	STOP SIGN. Turn left (south) paralleling R.R. tracks, up incline.

Mileage

00.45	45.68	STOP SIGN. Intersection with Belvidere Street. Turn right (west) for one short block.
00.05	45.73	STOP LIGHT at intersection of Sheridan Road and Belvidere. Turn left (south).
00.28	46.01	STOP SIGN. Turn half left. Sheridan Road becomes Genesee Road. Continue ahead.
00.15	46.16	STOP LIGHT at South Street. Continue ahead.
00.70	46.86	STOP LIGHT at 11th Street. Continue ahead.
00.40	47.26	STOP LIGHT. Abbott Laboratories on the left.
00.27	47.53	STOP LIGHT. Continue ahead to 22nd Street.
01.70	48.23	STOP SIGN. 22nd Street. Turn left (southeast) over R.R. tracks.
00.03	48.26	Turn right (south) after crossing tracks. Road is once again Sheridan Road. North entrance to Great Lakes Naval Training Center.
00.50	48.76	STOP LIGHT. Main gate to Great Lakes Naval Training Center. Proceed south on Sheridan Road.
00.40	49.16	FLASHING YELLOW LIGHT. Naval hospital on left. Entering Lake Bluff (pop. 5000).
01.85	51.01	Scranton Avenue in Lake Bluff. Turn left (east) into Village of Lake Bluff and continue eastward on Scranton Avenue.
00.83	51.84	Street ends at Lake Park. Turn right, then down bluff road through gate to sewage disposal plant.
00.15	51.99	Turn around in parking lot.

STOP NO. 6

FIGURE 6. ERODING TILL BLUFF JUST SOUTH OF THE SEWAGE TREATMENT PLANT AT LAKE BLUFF, ILLINOIS. SE¼ NE¼ Sec. 21, T. 44 N., R. 12 E., Lake County, Waukegan Quadrangle.

This exposure is a typical example of an actively eroding till bluff. The absence of a protective beach allows waves to strike with full force on the toe of the slope. This exposure is actively slumping and the slump material commonly covers the lower slope. Dead trees on the beach attest to the amount of material removed.

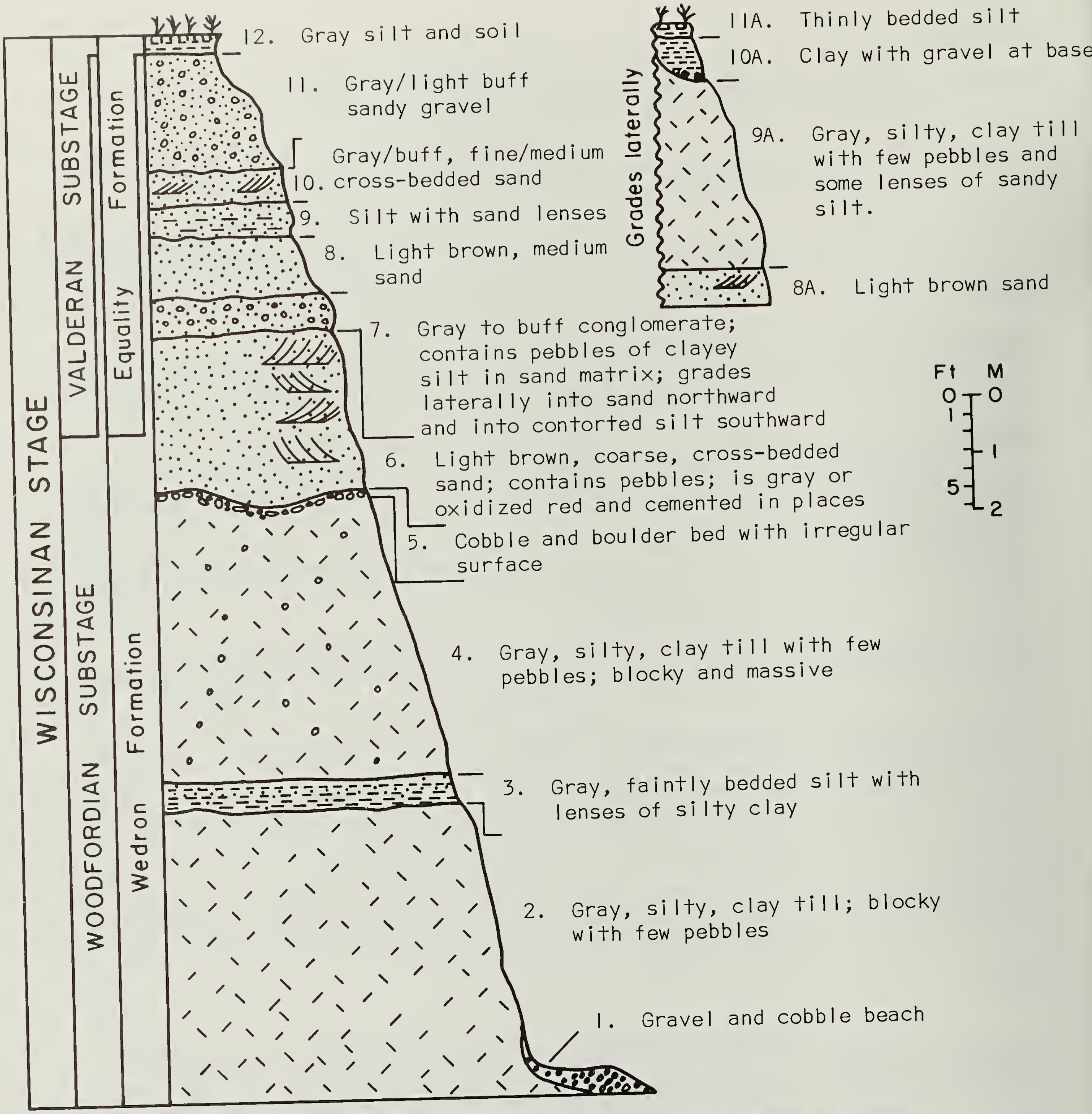

Fig. 6 - Stratigraphic section just south of Lake Bluff sewage disposal plant. SE¼ NE¼, Sec. 21, T. 44 N., R. 12 E., Lake County, Waukegan Quadrangle.

This bluff exposes three glacial till units and intercalated sand deposits belonging to the Wadsworth Till Member of the Wedron Formation. These tills are similar in mineralogy and grain size and are associated with various moraines of the Valparaiso and Lake Border Systems. The Wadsworth Till Member is the youngest glacial till exposed in Illinois, having been deposited about 13,500 radiocarbon years B.P. Characteristic mineralogy and grain size data for tills in the bluffs along Lake Michigan are given by Lineback later in this report.

The lower two tills (units 2 and 4) are separated by a bed of silt (unit 3) and make up about two-thirds of the bluff. There is a boulder bed (unit 5) at the top of the second till. About 3 meters (10 ft) of cross-bedded sand (unit 6) overlies the till. Above the sand is a bed composed of silty clay and rock pebbles in a sand matrix. This unit (7) grades northward within the outcrop into sand and southward into contorted silt. All units above the boulder bed are laterally gradational and badly slumped. Units 8 to 12 are exposed at the top of the northern part of the exposure. Units 8A through 11A are exposed in the central part of this bluff segment.

The upper till (unit 9A) is similar to the lower tills, but with slightly more silt and less sand. This till may be related to the Highland Park Moraine, the crest of which is 1.5 kilometers (0.9 mi) west of this site. Lying on the top of the till is 1 to 1.5 meters (3 to 5 ft) of thinly bedded silt, sand, and clay (unit 10A). A thin gravel bed separates this unit from the till. Clay beds in this unit may contain varves. Unit 10A is believed to be nearshore lacustrine sediments deposited during one of the highest lake levels of glacial Lake Chicago. This probably correlates with the Glenwood stage that here lies at about 200 meters (650 ft) above mean sea level. Unit 10A is therefore assigned to the Equality Formation. The Modern Soil (unit 11A) is developed in these lacustrine deposits.

A bore-hole located near the park entrance a block north of the exposure penetrated 6.0 meters (20 ft) of lacustrine silt and sand before reaching the till.

Factors encouraging erosion here include: (1) no protective beach or man-made structures to prevent the waves from striking the bluff, (2) materials that will quickly slump when the slope is oversteepened, (3) the removal of protective vegetative cover by earlier erosion, and (4) the presence of ground-water seeps that keep the material wet and prone to slump. Recession here is estimated to be at least 2 meters (7 ft) along the crest of the bluff since August 1973. Winter storms during 1974-75 are expected to result in continued removal of material from the bluff. The gravel beach indicates that fine material is quickly removed by wave action and currents.

BEACH AND NEARSHORE SEDIMENTATION WESTERN LAKE MICHIGAN

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Two time-series studies of the process-response mechanisms operating in the beach and inner nearshore areas of western Lake Michigan were conducted by the authors as part of a long-term field project (Fox and Davis, 1973a). The ultimate objective of this project is the quantitative prediction of coastal changes utilizing computer modeling techniques. The study areas at Sheboygan, Wisconsin (1972) and Zion, Illinois (1974) (fig. 7) which represent the only large stretches of sand beach on the western coast of Lake Michigan, were occupied for 30 and 15 days respectively during the summer. Such studies included frequent observations of environmental parameters and daily surveys of the beach and adjacent inner nearshore zone.

Among the environmental parameters measured were barometric pressure, wind speed and direction, wave period, breaker height and angle of approach, and longshore current velocity. Detailed topographic maps were prepared from daily surveys of a small portion of the coast; 1600 feet at Sheboygan and 800 feet at Zion. Comparison of daily maps by computer permits quantitative analysis of the changes in the beach and adjacent nearshore areas. Erosion and deposition data may be related to environmental variables, thus providing the framework for preliminary or conceptual models. These models are then formulated into quantitative simulation models which may have prediction capabilities. To date, such a simulation model has been developed for the eastern coast of Lake Michigan (Fox and Davis, 1973b) with gratifying results.

STUDY AREAS

The western coast of Lake Michigan has few stretches of well-developed sand beaches. There is a significant amount of gravel present on the beach and adjacent nearshore zone in both study areas. Gravel was the dominant beach sediment at Zion, Illinois, during the summer of 1974. Low coastal dunes

[1]Supported through Geography Branch, Office of Naval Research, Contract #388-092.

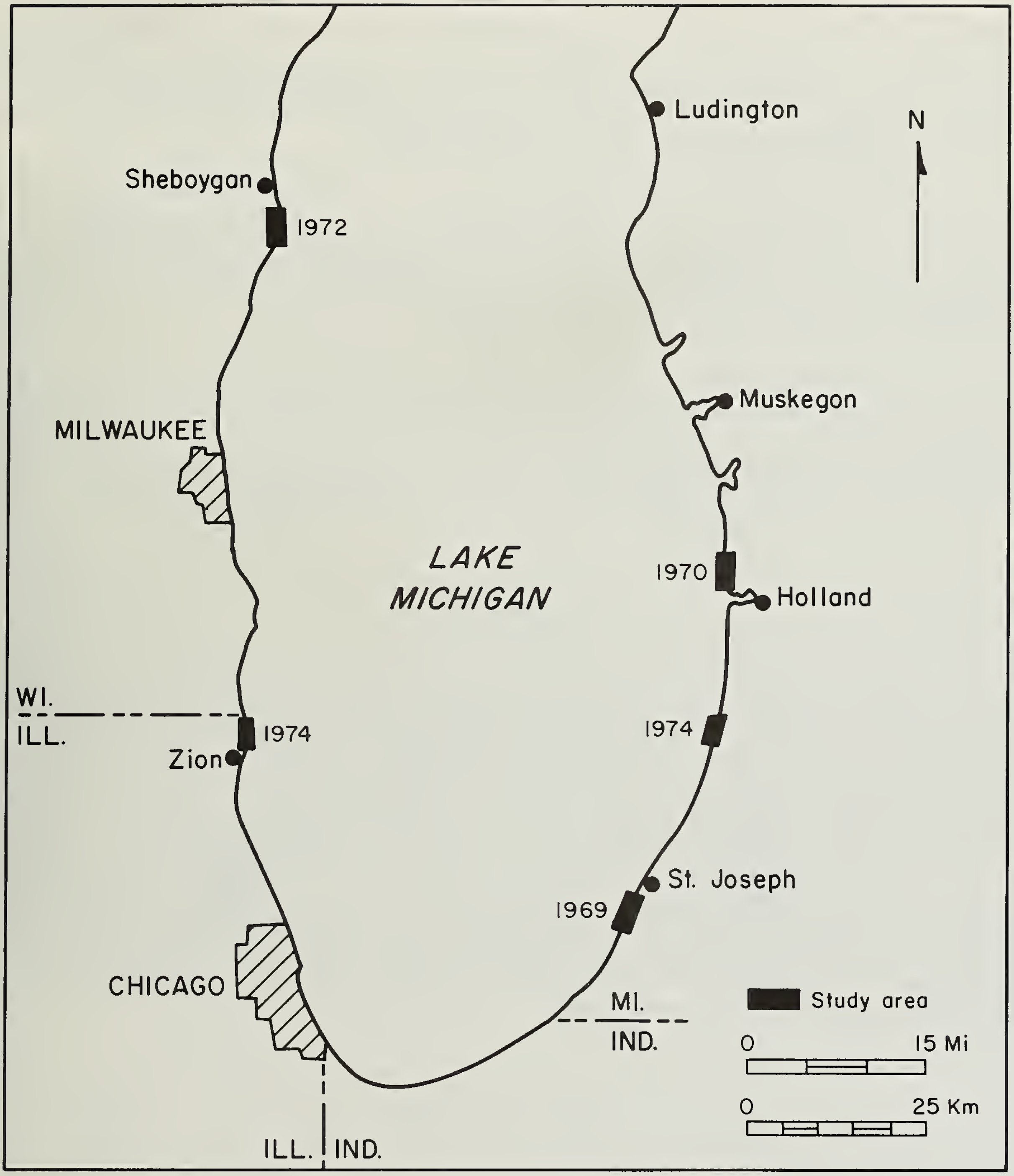

Fig. 7 - Index map showing location of study areas.

landward of the beach serve as a primary source of sediment for the beaches in both areas. The shoreline is slightly sinuous at both sites with the greater amplitude at Sheboygan. Late spring and early summer beach accretion were evident at both sites in the form of welded ridges of sediment and rather wide beaches, considering the recent lake level rises.

A marked difference existed between the longshore sand bars in the two areas. At Sheboygan there were two bars, one at a distance of about 100 feet from shore with its crest at a depth of 3.5 to 4.0 feet and another more continuous bar at a distance of 350 to 400 feet with its crest 6 feet deep. A single, continuous bar was present at Zion. It was about 300 feet from shore with its crest at a depth of 7 to 8 feet.

The slope of the inner nearshore was steeper at Zion. This, coupled with the absence of a shallow nearshore sand bar (fig. 8), caused some significant differences in the monitored variables at the two sites. The steep and effectively nonbarred configuration at Zion is an important factor in the recent erosion rates and will be discussed in more detail below.

METEOROLOGY

Any consideration of coastal sedimentation must include an analysis of the weather systems which affect the study areas and their relationships to coastal processes. Western Lake Michigan is in the belt of prevailing westerly winds and features cyclonic low pressure systems as the dominating energy-generating mechanism. During the summer months when field studies are conducted, these cyclones move in a west-to-east direction and pass across the Great Lakes area. Prevailing winds are from the south and southwest (fig. 9).

As the low pressure system approaches the west coast of Lake Michigan, winds are from the southwest to south-southeast along the beach. After the center of the cyclone passes over the west coast, there is a reversal of wind direction to the north. It is at this time that wind speed is generally quite high and large waves are generated.

COASTAL PROCESSES

Previous studies both on Lake Michigan and on marine coasts have demonstrated that fluctuations in barometric pressure are of prime importance in the generation of coastal processes and in the eventual morphologic responses. The periodic passage of cyclonic systems and the accompanying fall and rise in barometric pressure cause winds to change speed and direction. These in turn change the wave size and direction of wave approach. The waves themselves, coupled with the longshore currents which they generate, bring about significant changes to the beach and inner nearshore zone.

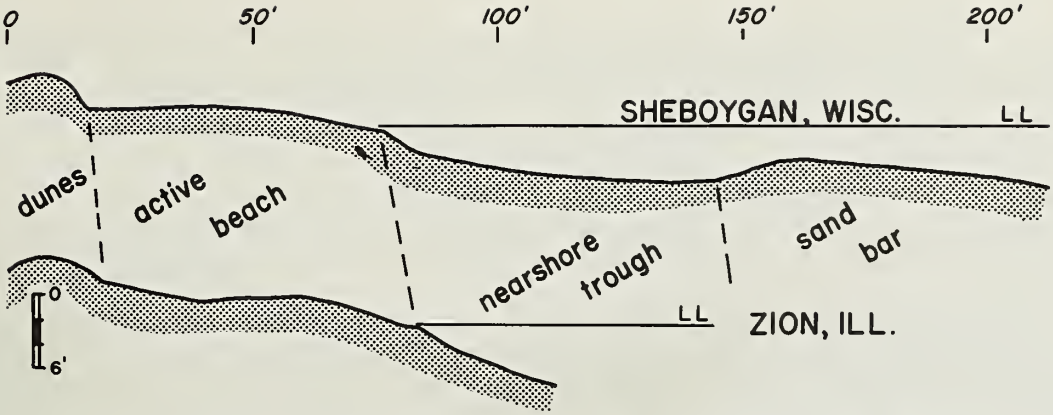

Fig. 8 - Beach and nearshore profiles at Sheboygan (above) and Zion (below).

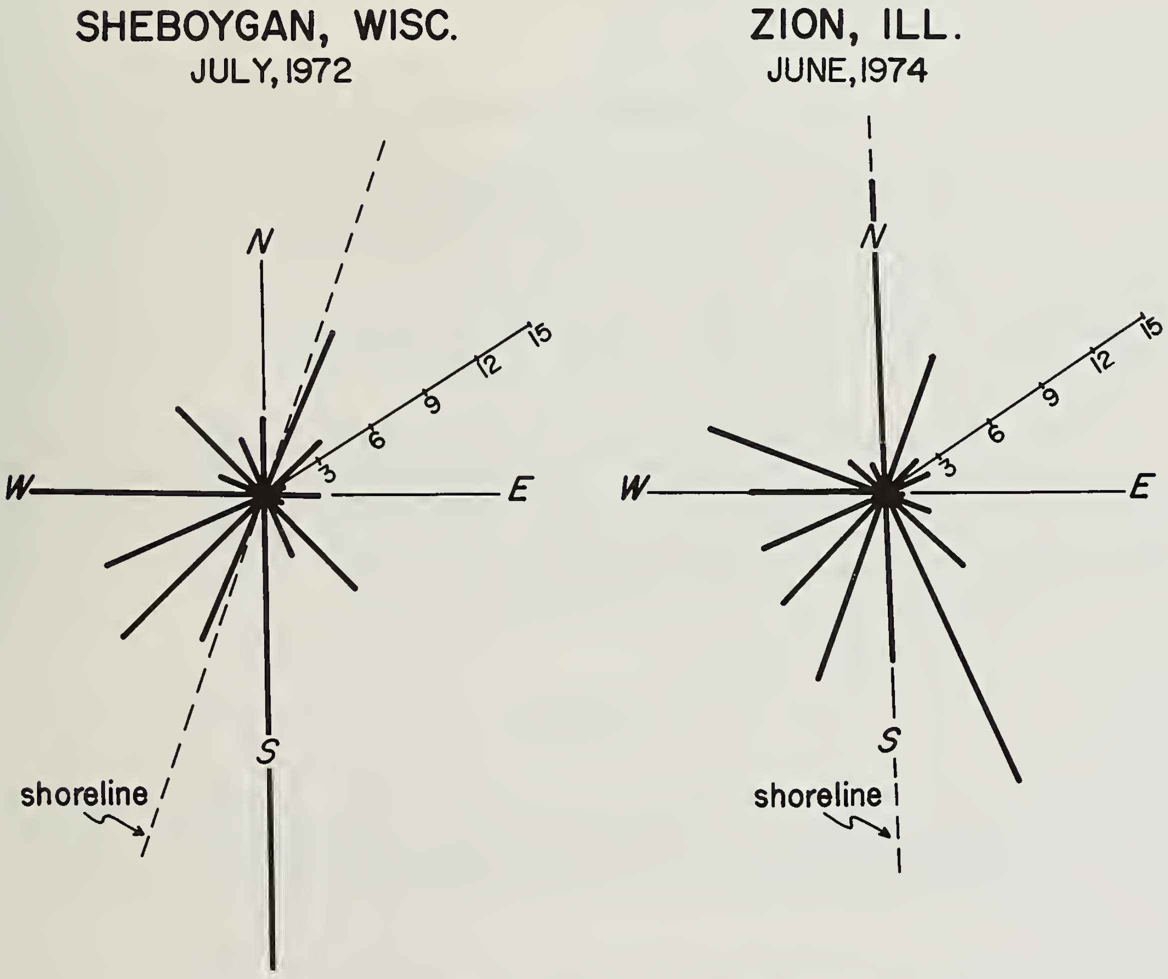

Fig. 9 - Wind direction and duration in hours for Sheboygan and Zion.

A generalized or conceptual model of western Lake Michigan coastal processes has been developed from detailed environmental data (fig. 10). As barometric pressure falls, winds from the south increase in speed causing an increase in breaker height and a swift, northerly flowing longshore current. Peak energy conditions occur just after the minimum barometric pressure values as the curve rises steeply (fig. 10). A reversal in wind direction occurs during the rise in barometric pressure and causes the direction of wave approach and longshore current to reverse also. This occurs as the energy level decreases.

The steep nearshore slope on the west coast of Lake Michigan coupled with a general absence of shallow sand bars permits waves to approach the shore with little refraction. As a result, longshore currents are not prominent except during storm conditions and then they are present only quite close to the shore. The net result is that the rate for coastal processes on the west coast of Lake Michigan is less than that on the east side. Sediment transport rates in the littoral zone would be expected to be correspondingly lower.

MORPHOLOGIC CHANGES

Because of the generally low energy conditions that prevailed during both periods of study, no large-scale morphologic changes were recorded. The steep slope and relatively deep bars dictate that the most marked changes occur on the foreshore beach. High energy periods at both study areas caused the same general changes with an increase in the amplitude of the shoreline sinuosity. During subsequent periods of low energy, the shoreline was somewhat straightened with protuberances eroded slightly and accretion occurring in the embayments.

The above morphologic changes, which reflect the prevailing conditions, do not take into account the severe winter storms. Such phenomena are responsible for the vast majority of the coastal changes, especially the rapid retreat of the shoreline during the past few years. It is critical to understand that nearly all erosion takes place during only a few storms per year.

SUMMARY

Coastal processes along western Lake Michigan respond directly to low pressure systems that move in a generally west to east direction. Changes in the coastal processes, especially breaker height and direction of approach, and longshore current velocity and direction, are predictable, at least semi-quantitatively.

The steep nearshore slope and the position of longshore sand bars along western Lake Michigan permit waves to approach the shore with little or no effect from the bottom. Therefore, wave energy at the water's edge is quite high. In addition, the depth of water causes little refraction until the waves are only a few feet from shore. This results in a narrow, effective, longshore

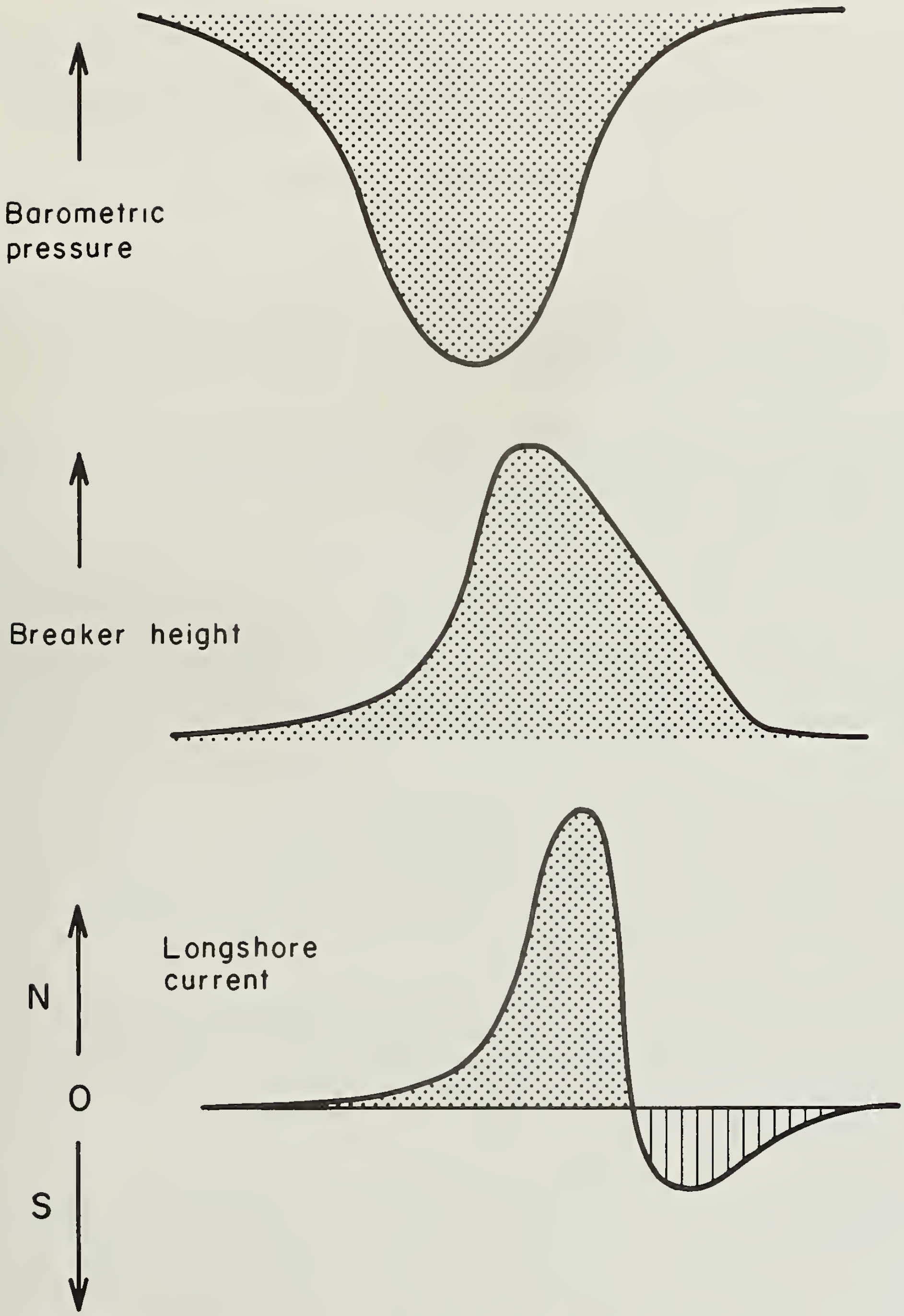

Fig. 10 - Diagram illustrating relationship between barometric pressure, breaker height, and longshore current direction for Zion beach study.

current for transporting sediment. Consequently, there is less lateral sediment transport with respect to onshore-offshore transport than on a coast with a less steeply inclined nearshore such as in eastern Lake Michigan.

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Fox, W. T., and R. A. Davis, 1973b, Simulation model for storm cycles and beach erosion on Lake Michigan: Geological Society of America Bulletin, v. 84, p. 1769-1790.

ENGINEERING GEOLOGY OF THE LAKE MICHIGAN BLUFFS FROM WILMETTE TO WAUKEGAN, ILLINOIS

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Illinois State Geological Survey

The 30- to 100-foot high bluffs that extend along the lake shore from Wilmette to Waukegan provide excellent vantage points of the lake, adding appreciably to the value of lakefront property. With lakefront exposure, however, come the hazards of bluff erosion which are especially evident during periods of high lake levels. The rapid recession of portions of the bluff has led the Illinois State Geological Survey, as part of a broad coastal data gathering program, to begin a series of studies to determine the rates, locations, and reasons for abnormal bluff erosion by means of synoptic aerial surveys, stratigraphic analyses, and measurements of engineering properties such as slope, water content, compressible strength, Atterberg limits, and mineral composition.

Six borings spaced every few miles along the bluff have been completed thus far (fig. 11) and more are scheduled. The holes were drilled within a few hundred feet of the bluff for the purpose of correlating subsurface data with descriptions and analyses made of samples taken from the bluff face.

Dames and Moore, Consulting Engineers of Park Ridge, Illinois, are cooperating in the study through the participation of Allen Perry, who will use portions of the study for a Ph.D. research program. Engineering tests of samples are being carried out by the Illinois State Geological Survey and Dames and Moore.

Extensive soil property data are essential to good design practice in construction but funds for acquisition are limited. Consequently, plans call for taking full advantage of information already in the files of local engineers and consultants. Preliminary discussions with some of these firms indicate a ready willingness that this data be used to advantage in the study.

The goals of the engineering geology study are to correlate the stratigraphy and engineering properties of the bluffs and to make the results available through a cumulative central file as well as through publications and conferences. A better understanding of the materials in the bluffs will greatly enhance the success of structural and nonstructural plans instituted along the Lake Michigan shore and in time may lead to a stabilized and well managed coastal zone.

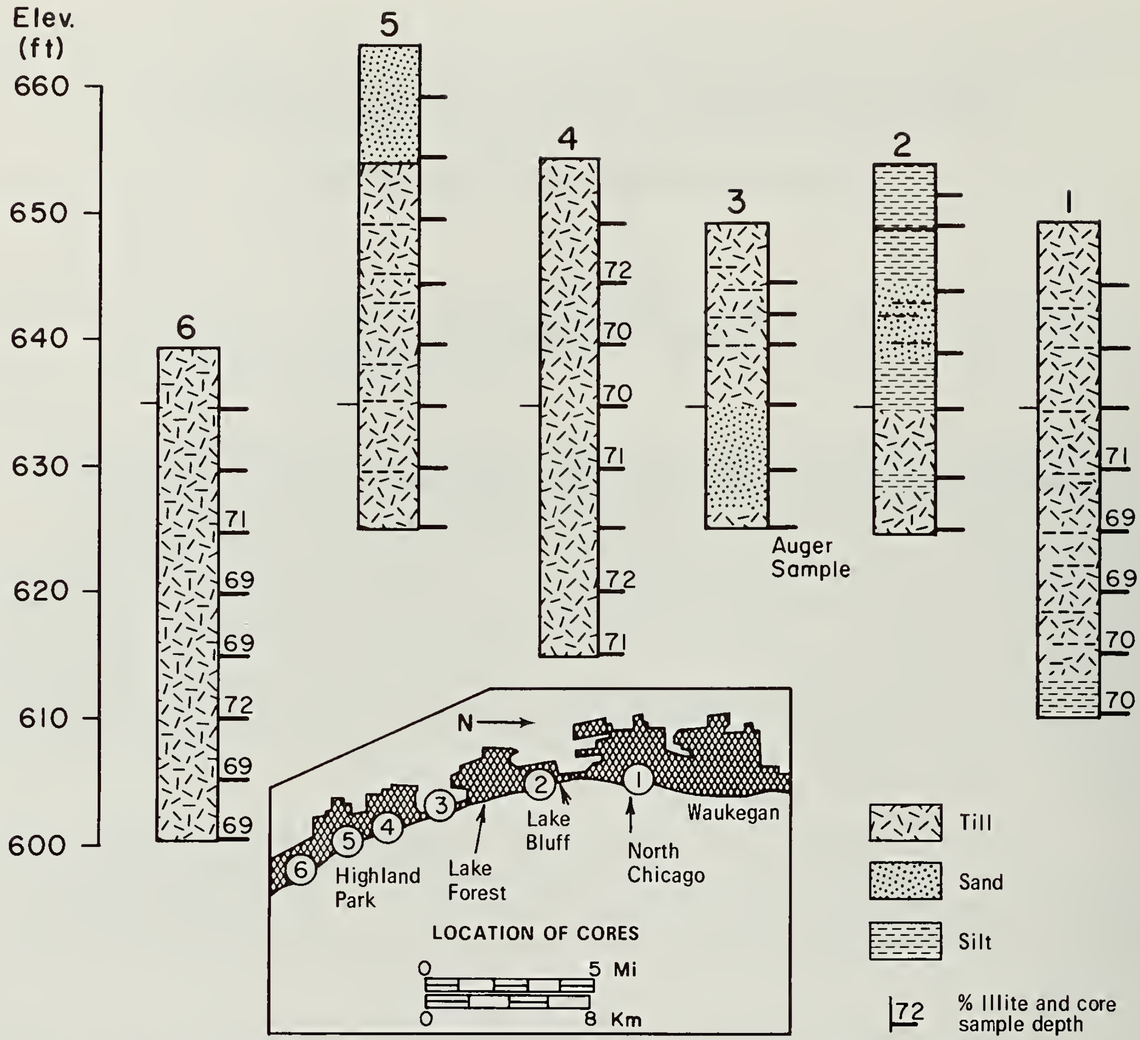

Fig. 11 - Diagram of materials encountered in research borings in the Northshore bluff. Locations are shown in the inset index map.

EROSION OF TILL BLUFFS: WILMETTE TO WAUKEGAN

Jerry A. Lineback

Illinois State Geological Survey

The physical interaction between Lake Michigan and its shoreline commonly works to the detriment of the shore, especially during periods of high water level. Consequently, erosion is presently taking place at many sites along the shoreline in Illinois. Many factors affect the extent and location of the damage. Among these are waves and currents, water levels, orientation and topography of the shore and nearshore, composition of materials comprising the shore, and the extent and configuration of man-made structures.

The portion of the Lake Michigan shore from Wilmette to Waukegan is lined with bluffs composed of till (Wedron Formation) with intercalated sands, silts, and clays. The till bluffs rise from about 10 meters (30 ft) above the lake just north of Wilmette to about 30 meters (100 ft) near Highland Park. The topography results from the presence of the Highland Park Moraine, one of the Lake Border Moraines, that was deposited as the Woodfordian age glacier began to withdraw from Illinois about 13,500 radiocarbon years B.P. (fig. 12). The material in the moraine is mostly till with several intercalated beds of glacial-lacustrine silts and sand, and some sandy glacial outwash. All are assigned to the Wadsworth Till Member of the Wedron Formation. At least three till beds can be identified (fig. 13), and all have similar characteristics and composition. North of Highland Park, the till is overlain by lacustrine sand and silt (Equality Formation) deposited when one of the early stages (Glenwood) of ancestral Lake Michigan stood at about 195 meters (640 ft) above sea level. The till contains very little gravel and larger sized material (table 2). The matrix contains 5 to 20 percent sand. Silt and clay comprise the remainder, with clay slightly more abundant than silt. Illite is the dominant clay mineral. The till is layered in places with bedding thickness of 30 centimeters. It is gray or brown, and, where the till is brown, it commonly contains more pebbles.

TABLE 2—AVERAGE COMPOSITION OF THE WADSWORTH TILL MEMBER OF THE WEDRON FORMATION IN NORTHSHORE BLUFFS (29 samples)

<u>Grain size</u>
Sand 10%, Silt 42%, Clay 48%
<u>Clay minerals in <2μ fraction</u>
Expandables 7%, Illite 73%, Kaolinite-Chlorite 20%
<u>Carbonate minerals in <2μ fraction</u>
Calcite, 42 counts per second; Dolomite, 57 counts per second

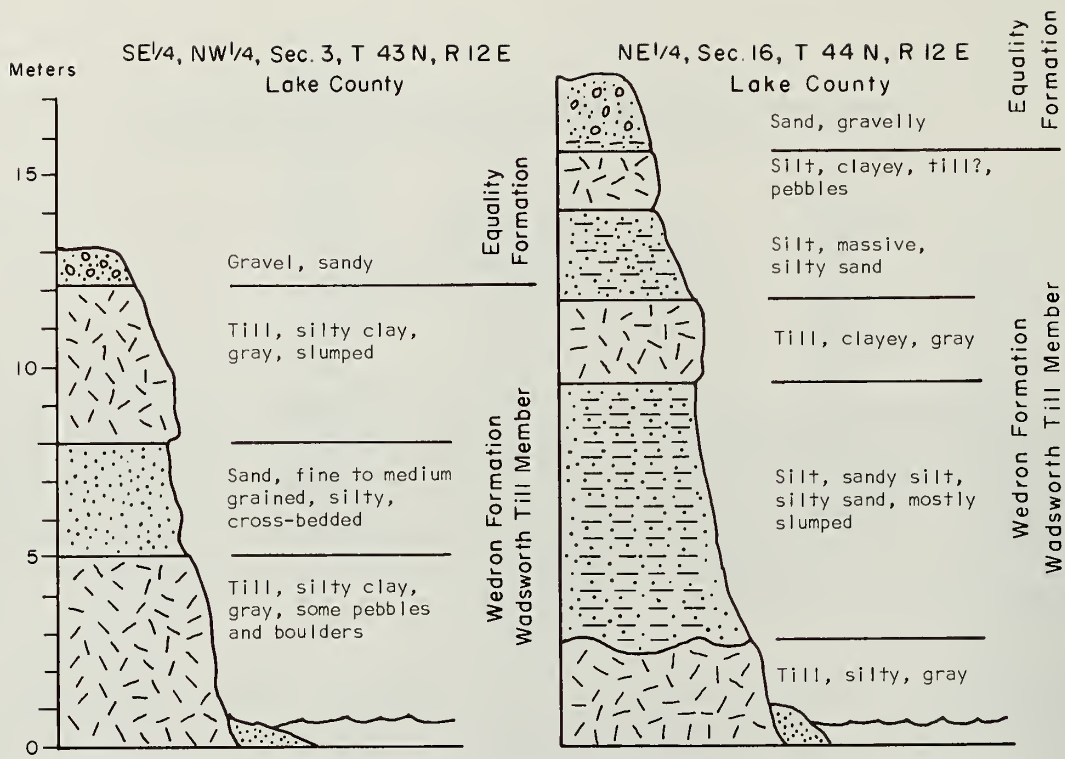

Fig. 12 - Representative stratigraphic sections from the northern part of the till bluff area showing multiple till units in the Wadsworth Till Member.

The primary use of the shore between Wilmette and Waukegan is low-density residential, with two military installations (Fort Sheridan and the Great Lakes Naval Training Center). The bluff is oversteepened by wave erosion at the base, and about 10 percent of the bluffline is presently undergoing active erosion with slumping and recession of the top of the bluff (plate 4). Most of the rest of the bluff has suffered some damage but is partially protected by man-made structures and vegetation. The shore from Waukegan north to the state line consists of a more or less stabilized till bluff or high-level lake plain underlain by till, with an extensive beach ridge complex up to 1.8 kilometers (1.1 mi) wide between the bluff and the lake.

Inclusions of pebbly silt in the till are present in places and are more easily eroded by wave action than is the till. Beds of stratified material between beds of till range from a few centimeters to several meters in thickness. They range from massive silt to sand with large scale cross-bedding. The amount of water-laid material is greatest between Lake Bluff and the Great Lakes Naval Training Center. Beds of stratified material are less stable in the slopes than in the till and contribute to slumping. Springs and seeps along the bluffs indicate that ground water is moving through the sediments; increased pore pressure from ground water contributes to the slumping of the oversteepened slopes.

High lake levels tend to accelerate lake shore erosion around the Great Lakes. Lake Michigan exhibits seasonal fluctuations of about 30 centimeters. The peak high occurs in late summer. Since 1860, recorded lake levels show long-term fluctuations of about 2 meters with periods ranging from 8 to 20 years between highs. High levels are reached during and just after periods

characterized by high precipitation in the lake region. The present lake level is about as high as any recent recorded levels. As a result, accelerated erosion is taking place. The chief effect is the removal of the wide sand beach that protects the shore at low water levels, undercutting of the till where waves beat directly on the toe of the bluff, slumping by the upper bluff, and removal of the slumped materials by longshore and offshore currents (pl. 5).

EROSION RATES

Erosion rates vary from place to place depending on local conditions. Much of the till bluff presently shows little slumping and erosion. About 10 percent of the bluff line, however, has been denuded of its vegetation and is rapidly being removed. Long-term (1939-1964) recession rates of the bluff, measured from aerial photographs, range from zero to about 1.5 meters (5 ft) per year. As much as 122 meters (400 ft) of recession per year has been recorded during historic times.

SEDIMENT DISPERSAL

Sediment generated by wave erosion is large in volume but is rapidly removed from the area, permitting continued erosion. Sediment dispersal patterns can be determined by observing bands of turbid water in the lake from earth-orbiting satellites. Data for 18 days between August 1972 and August 1973 have been recorded by the ERTS-1 satellite and related to local wind conditions. The dominant wind direction (39 percent of the time) is from the southwest. Prevailing southwesterly winds tend to move water and suspended sediment from the nearshore zone toward the northeast (pl. 6 and facing fig. 13). Several images show that these northeasterly trending sediment plumes turn to the southeast several miles offshore where they meet the southward moving longshore current. The net loss of sediment is to the south, and the sand appears to be distributed over the nearshore lake floor. Only very coarse material is retained along the shore during high lake levels. During low lake levels, however, sand accumulates in the beach zone and finer materials are removed offshore.

CONCLUSIONS

About 10 percent of the till bluffs between Wilmette and Waukegan are undergoing active erosion. The remainder have been damaged but are protected by sea walls or vegetation. Present high lake levels have resulted in waves and currents removing the protective sand beach, allowing direct access for waves to the toe of the bluff. Sediment derived from erosion is carried from the shore by combination of wind-induced currents and longshore drift. Accelerated erosion will continue until the water level drops to the point where a significant beach can be reestablished. Rates of bluff recession range as high as 1.5 meters (5 ft) per year in areas of active erosion.

PLATE 4

Significant erosion is taking place along unprotected segments of the Lake Michigan shoreline. The pictures show the changes that occurred between August 1973 (top picture) and March 1974 (bottom picture) at a location on the shore between Elder Lane Park and Lake Front Park in Winnetka, Illinois (center south line NE¼ Sec. 21, T. 42 N., R. 13 E.). The August picture shows a new vertical wave-cut face at the toe of the bluff. The beach is narrow, and no structures prevent waves from striking the bluff. Lenses of gravelly silt in the till are easily eroded and create pockets along the bluff. Note the position of the large forked tree. The bottom picture was taken after winter storms and shows that the over-steepened bluff has slumped. The toe is covered with slump debris and the top part is nearly vertical. The forked tree and a significant portion of yard have been removed.

PLATE 4

PLATE 5

Aerial photographs taken in 1964 (A) and 1973 (B) of a portion of the till bluffs near Fort Sheridan, showing that the wide beach present in 1964 has largely been removed during the high-water levels of 1973. At Station 1, 11.6 meters (38 ft) of beach was lost; at Station 2, 28.3 meters (93 ft); and at Station 3, 15.2 meters (50 ft). At Station 4, 23.8 meters (78 ft) of beach and 10.4 meters (34 ft) of bluff have been removed.


1000'
4
3
Runway
2
Fort Sheridan
A
1
1000'
4
3
Runway
2
Fort Sheridan
1
B

PLATE 5

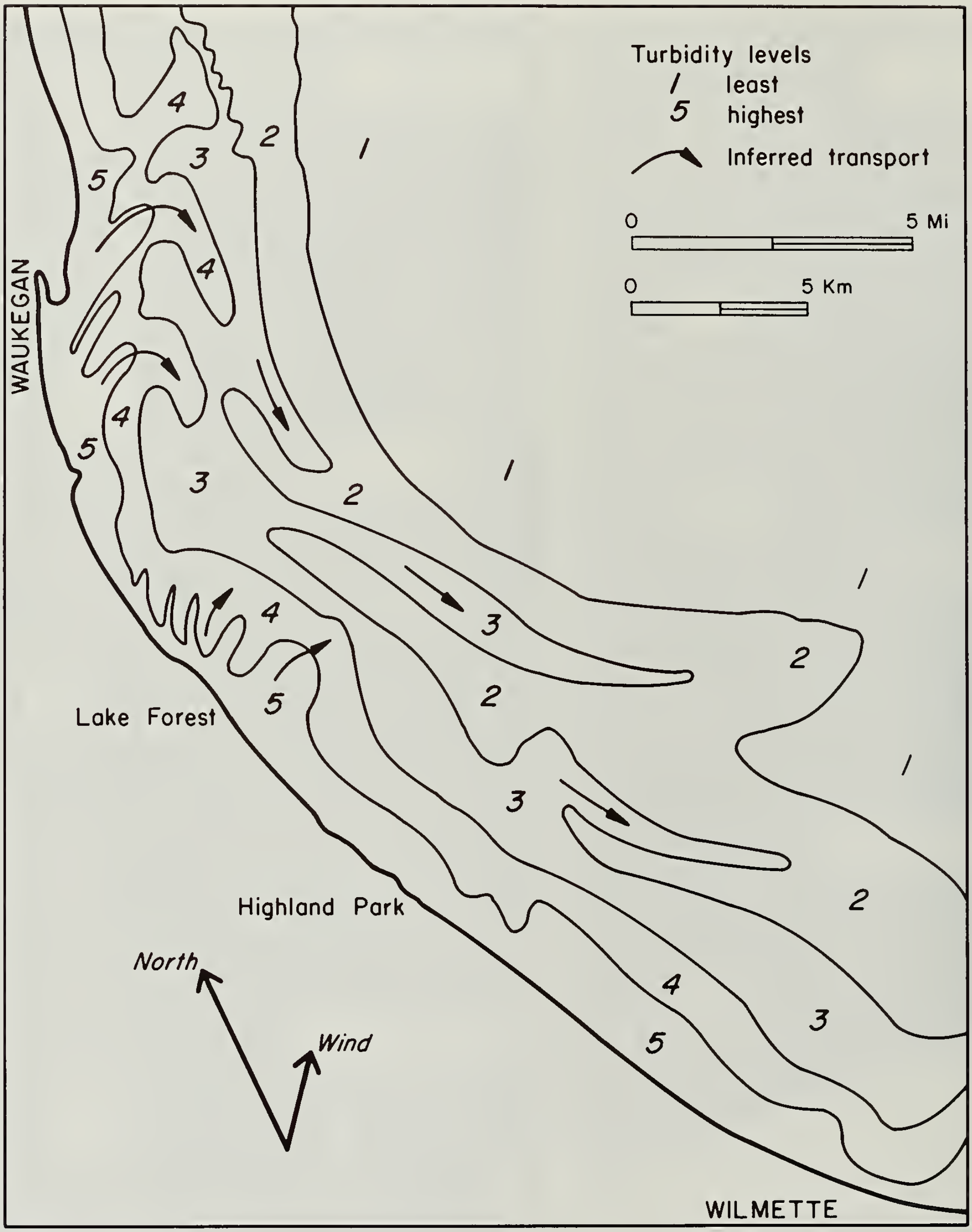

Fig. 13 - Interpretive diagram of enhanced ERTS-1 frame 1124-16050. See caption to plate 6 for explanation.

PLATE 6

Enhanced ERTS-1 frame 1124-16050 (opposite page) and interpretive diagram (above), multispectral scanner band 5 (red), taken November 24, 1972, showing sediment plumes in Lake Michigan between Wilmette and Waukegan. Arrows indicate direction of sediment plume growth. Numbers indicate relative density of suspended sediment. The number 5 indicates maximum density; 1 indicates minimum.

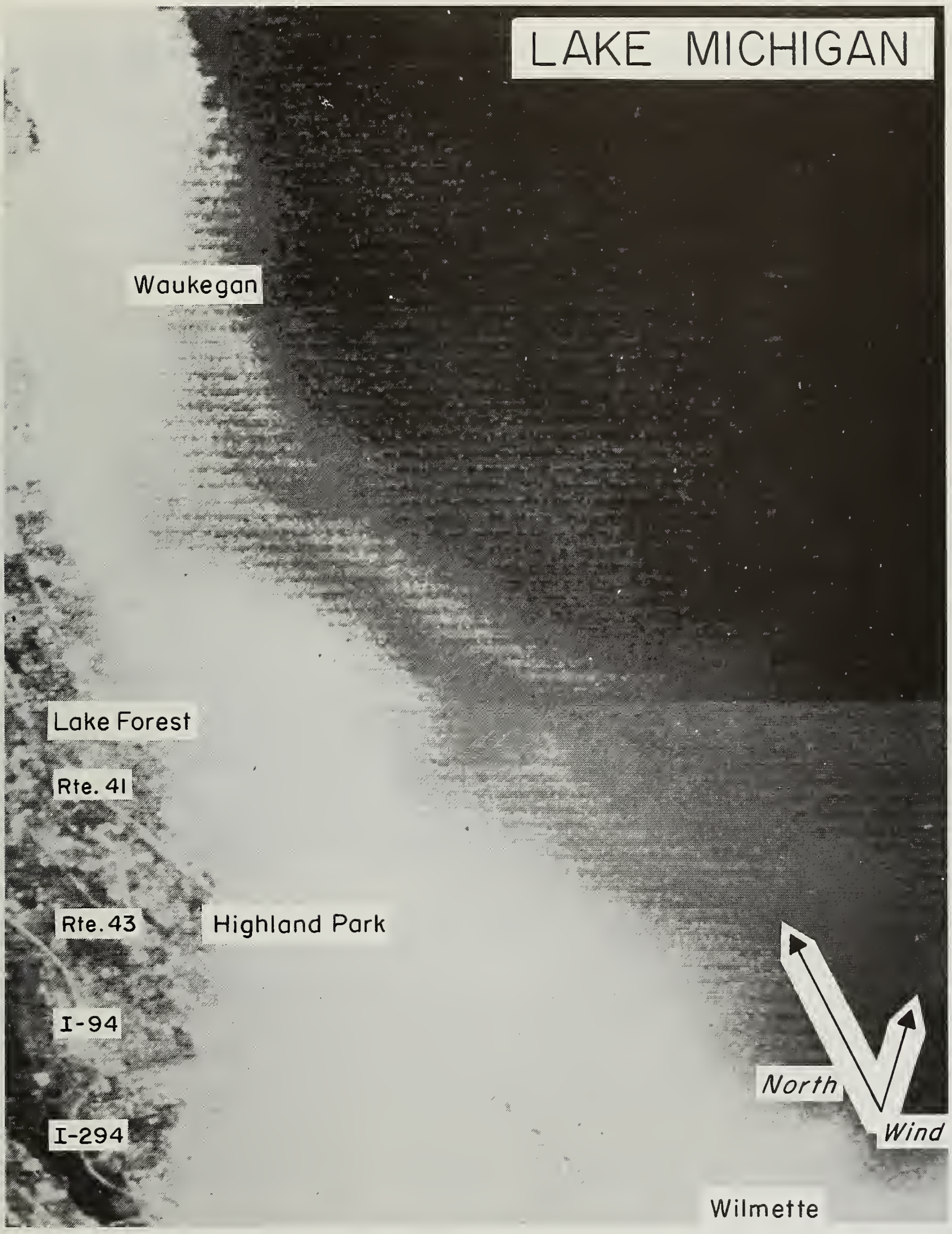
LAKE MICHIGAN
Waukegan
Lake Forest
Rte. 41
Rte. 43
Highland Park
I-94
I-294
North
Wind
Wilmette

PLATE 6

LATE HOLOCENE LAKE LEVELS IN SOUTHERN LAKE MICHIGAN

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The return of high lake levels in recent years has greatly revived interest in the prediction of future high water levels and with it the topic of Holocene lake levels by which future levels may be judged. The highly detailed studies of raised beach features originally reported by Leverett and Taylor (1915) form the base of the classic literature. In the 1950s, Bretz (1955) and Hough (1958) reopened this research wherein complex models of crustal deformation and movements of major ice fronts were invoked to explain a vast number of relict coastal and fluvial features. It is now apparent that much of this early work, while provocative and informative, lacked the precise temporal control now available through improved ^{14}C dating techniques. In addition, more is known today regarding ongoing post-glacial isostatic rebound in the Great Lakes region (Clark and Persoage, 1970).

Lewis (1969, 1970) recently provided a collection of ^{14}C dates from late Holocene beach features and stratigraphic sections for northern and southern Lake Huron. These provide important evidence for the time of occurrence of the traditional Lake Nipissing (elev. 183 m/600 ft) and Lake Algoma (elev. 180 m/591 ft) stages of Lake Michigan-Huron. In brief, Lewis placed the Lake Nipissing stage between 5500 and 3900 ^{14}C years ago. By the latter date, the lake had dropped to the Lake Algoma level that was maintained until about 2500 ^{14}C years ago. The present level of 176.8 meters (580 ft) was attained sometime after this period. This model is based largely on those of Leverett and Taylor (1915) and Hough (1958).

The purpose of this research has been to pursue similar chronological studies on the southern shores of Lake Michigan. In addition to the lack of ^{14}C control there, the area is well south of the Lake Nipissing and Algoma "hinge lines" of Leverett and Taylor (1915) and Hough (1958) and hence potentially undisturbed by active glacial rebound (see, for example, the model of Clark and Persoage, 1970). Thus, the southern Lake Michigan record of late Holocene lake level events may be preserved in greater detail than elsewhere because it has been little influenced by crustal movements.

Three previous studies have suggested the occurrence of a variety of post-Algoma lake level fluctuations. Detailed stratigraphic studies made in connection with archeological excavations near the Straits of Mackinac (McPherron, 1967) and in Saginaw Bay, Michigan (Speth, 1973) indicate the presence of two separate high lake levels as much as 2 meters (6.6 ft) above the present level (176.8 m/580 ft). More recently, Illinois State Geological Survey studies have documented a similar high fluctuation that may have taken

place about 1200-1400 A.D. (Hester and Fraser, 1973; Fraser and Hester, 1974). The latter evidence came from a beach-ridge complex located between Kenosha, Wisconsin, and Waukegan, Illinois. These authors also reported important evidence of peat from the base of an inter-ridge marsh at an elevation of 175.6 meters (574 feet)—a suggestion of an extended low fluctuation of at least 2 meters (6.6 ft) below the present level which occurred about 785 A.D. Traditional models account for the drop in lake level from Lake Nipissing (183 m/600 ft) to Lake Michigan-Huron (176.8 m/580 ft) by means of differential erosion of outlets at Port Huron and Chicago. No provision, however, was made for extended lake levels below elev. 176.8 meters (580 ft).

While no definitive evidence is presented here, pending results from 20 new ^{14}C samples now being processed, it is nevertheless possible to draw a broad outline of late Holocene lake levels based upon 16 recent and 3 earlier but pertinent dates. These are tabulated in table 3.

Field work was carried out between Kenosha and Waukegan during the spring of 1974 with special emphasis directed toward investigating specific landforms—the beach-ridge complex and tributary streams west of the complex. Cores were taken in inter-ridge marshes north of Illinois Beach State Park (fig. 14). In each core, marsh peats or organic sands were found overlying beach or nearshore sands. Radiocarbon dates on these organic deposits give an approximate date of their formation as well as a younger limit for the age of the underlying sands. Prior lake levels that formed the underlying beach and nearshore deposits probably were no higher than the elevation encountered. A combination of these data provides a tentative basis for reconstructing recent past fluctuations. Of great value in the reconstruction is evidence for a distinct north-south progression of successive beach ridges. This relationship was suggested by Hester and Fraser (1973) and is verified here. The preliminary time-space deposition scheme is presented in figure 14. Dated ridge sequences south of cores 8 and 9 are based on unpublished archeological information. The 1872 shoreline is derived from U.S. Army Corps of Engineers data (1953).

Stratigraphic sections were described along four tributary streams. In the case of Barnes Creek south of Kenosha, a 3 meter (9.8 ft) section is generally exposed across the sand body in an east-west stream cut. Part of this section (columns 1 to 4) and several cores (columns 5 to 9) taken from marshes are shown in figure 15. With the exception of Barnes Creek, ^{14}C dates are not yet available for alluvial fill samples that may date terraces. There appear to be, however, at least three post-Nipissing terrace systems. These are found at 2.4 meters (8 ft), 1.4 meters (4.5 ft) and 0.75 meters (2.5 ft) above the existing stream beds and were found in at least three of four stream systems observed. In addition, organic silts containing abundant wood fragments and branches have been observed to extend upstream to about elevation 183 meters (600 ft) in three of the stream systems. These silts are interpreted as marsh deposits caused by ponding of water downstream because of temporary obstruction, or more likely, a higher lake level. The elevation of these deposits suggests that they are referrable to the Lake Nipissing stage. Alluvial terraces probably also result from base level changes caused by lake level fluctuations.

TABLE 3—RADIOCARBON DATES

Lab no.	Material	Age in ^{14}C years	Elev. of sample (meters)	Lake surface at time of deposition (meters)	Reference
Illinois Beach State Park*					
ISGS-168	Peat	715 ± 75 B.P.	176.8	≤176.8	Hester & Fraser, 1973
ISGS-169	Peat	1165 ± 75 B.P.	175.0	≤175.0	Hester & Fraser, 1973
ISGS-182	Peat	540 ± 75 B.P.	176.6	≤176.6	Hester & Fraser, 1973
Kenosha, Wisconsin†					
ISGS-185	Wood	6350 ± 140 B.P.	177.8	≤177.8 ?	Hester & Fraser (unpublished)
ISGS-187	Wood	7370 ± 90 B.P.	178.1	-	Hester & Fraser (unpublished)
ISGS-189	Wood	5315 ± 75 B.P.	177.2	≤177.2	Hester & Fraser (unpublished)
Beach Ridge Complex‡					
ISGS-217	Peat	3130 ± 100 B.P.	177.8	≤177.8	this paper
ISGS-218	Peat	2980 ± 130 B.P.	177.6	≤177.6	this paper
ISGS-225	Peat	2280 ± 130 B.P.	177.8	≤177.8	this paper
ISGS-224	Peat	2275 ± 75 B.P.	176.7	≤176.7	this paper
ISGS-253	Peat	765 ± 75 B.P.	179.3	≤179.3	this paper
ISGS-265	Organic sand	3275 ± 75 B.P.	178.7	≤178.7	this paper
Barnes Creek, Wisconsin§					
ISGS-259	Wood	4740 ± 75 B.P.	179.0	≤179.0	this paper
ISGS-260	Wood	4890 ± 75 B.P.	178.4	≤178.4	this paper
ISGS-263	Organic sand	560 ± 75 B.P.	180.0	≤180.0	this paper
North Branch Channel, Chicago River#					
ISGS-266	Shell	4300 ± 75 B.P.	177.2	≤183.0	this paper
RELATED DATES					
North Branch Channel, Chicago River					
W-425	Wood	5370 ± 200 B.P.	177.2	≤177.2	Willman & Frye, 1970
Michigan City, Indiana¶					
I-362	Wood	5475 ± 250 B.P.	176.7	≤176.7	Winkler, 1962
I-363	Wood	6350 ± 200 B.P.	176.0	≤176.0	Winkler, 1962

TABLE 3—RADIOCARBON DATES—Continued

*Peats are from the base of extensive inter-ridge marshes west of park. Below the peats are beach and nearshore sands with an undulating surface similar to the present ridge complex.

†ISGS-189 was obtained on wood from a paleosol exposed along the shore just south of South Park. Wood has been identified as oak and ash and has been published elsewhere with a 6340 ± 300 B.P. date (Sander, 1969). ISGS-185 and 187 were made on redeposited material from nearshore sand overlying ISGS-189. The sequence shows a post 6340-5315 B.P. transgression of the lake to 177 m (580 ft), but more exact dating of the in-place material is necessary.

‡Peats and organic sand are from inter-ridge marshes north of Illinois Beach State Park. Marshes here are also underlain by beach and nearshore sands.

§Both wood samples are from marsh silts overlying stiff lake deposits and glacial till. These silts are overlain by fluvial sands and gravels, and beach or nearshore sands. A paleosol developed on the nearshore or beach sands furnished ISGS-263.

#Shell is from "*Unio* bed" discovered by F. C. Baker in 1914 (Baker, 1920). Depth range for *Elliptio crassidens* in this assemblage is 1.5 to 6 m (4.9 to 19.7 ft). This implies a possible lake level of 183 m (600 ft). W-425 was done on wood from marsh deposits underlying the "*Unio* bed."

¶Date I-362 is from upper of two marsh clay-silts that outcrop along beach west of Michigan City. Ostracod genus *Cyclocypris* and grass fragments suggest marsh environment. Lake surface was near or below elev. 177.2 m (581 ft) at time of deposition. This bed is overlain by 3 to 6 m (9.8 to 19.7 ft) of nearshore sand. Date I-363 is from lower of two clay-silt beds discussed above. Lake surface is inferred to be at or below elev. 176.0 m (577 ft) at the time of deposition. Lacustrine sand separates both clay-silt beds, perhaps indicating a brief transgressional event or an isolated storm.

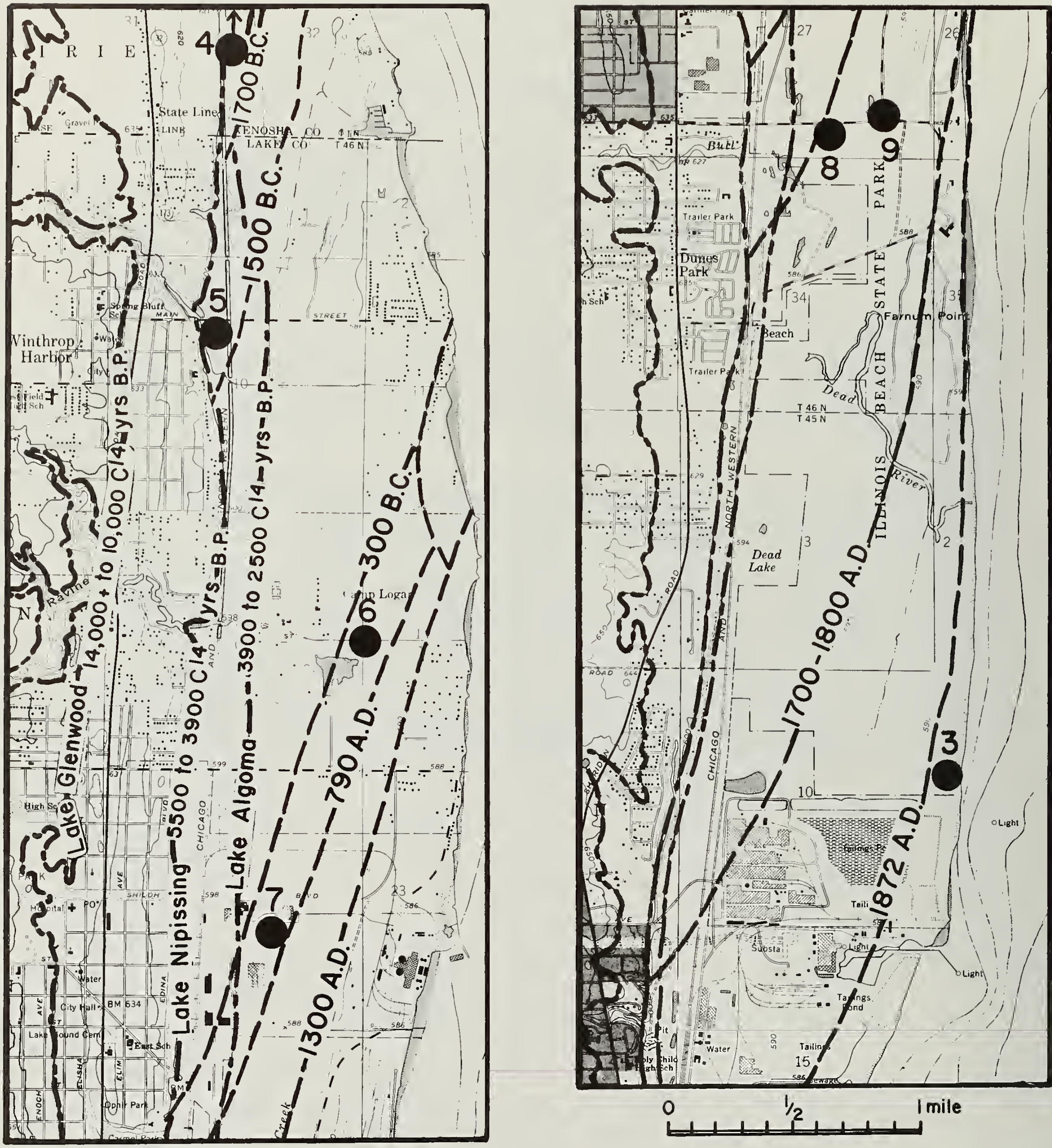

Fig. 14 - Diagram showing preliminary age determinations for beach ridges in the Zion Beach Ridge Complex based on radiometric and archaeologic dating. Approximate shorelines are also given for the Glenwood, Nipissing, and Algoma Lake Stages. Numbered dots refer to sections given in figure 15.

More information on lake level changes in southern Lake Michigan comes from Chicago and Michigan City, Indiana. Sections exposed during the excavation of a canal between Lake Michigan at Wilmette and the Chicago River were discovered by F. C. Baker in 1914 (Baker, 1920). Certain of these exposures were reexamined by the author and were sampled. In addition, mollusk shells collected by Baker and deposited with the Illinois State Geological Survey were dated. Most significant was a 4300 ± B.P. date (ISGS-266) from the "*Unio* bed" continuously exposed for up to 3 kilometers (1.86 mi) near Foster Avenue. Pelecypods and gastropods create a thick zone on top of a sand and gravel layer that varies in elevation from 177 meters (580 ft) to 179 meters (587 ft). The presence of *Elliptio crassidens* in this assemblage calls for a depth of 1.5 meters (4.9 ft) to 6 meters (19.7 ft) in clear moving water (Baker, 1920). This implies a lake level as high as 183 meters (600 ft) for this period. Marsh silts containing branches and twigs below the "*Unio* bed" were dated by Leighton at 5370 ± 200 B.P. (Willman and Frye, 1970). These dates mark a rise to the Lake Nipissing high from a level near the present.

Dated sections at and below present lake level near Michigan City, Indiana, show marsh deposits containing grasses, wood, and shallow water ostracod faunas. Two distinct beds are separated by lacustrine sands. The lower silt dates at 6350 ± 200 B.P. (I-363) while the upper is 5475 ± 250 B.P. (I-362 in Winkler, 1962). This section is in turn overlain by 3 meters (9.6 ft) to 7 meters (22.4 ft) of beach and nearshore sand. A lake level slightly below the present may be indicated by marsh silts. The overlying nearshore sands indicate a later lake level of 183 meters (600 ft). This is consistent with dated stratigraphy at Chicago.

Figure 16 is a preliminary interpretation of late Holocene lake levels for Lake Michigan-Huron based upon the information collected thus far. While the overall downward trend is similar to earlier conceptions, the presence of major fluctuations is not. It seems plausible that earlier researchers may have derived their late Holocene interpretations essentially from evidence of past high lake levels.

Paleoclimatic changes may offer an alternative to traditional models that rely on crustal deformation to explain the Lake Nipissing high lake level of Lake Michigan-Huron. A downward trend to the near present level can also be explained using the same methods. The Nipissing high as well as post-Algoma highs reported by Speth (1973), McPherron (1967), and Hester and Fraser (1973) appear to be synchronous with well established periods of glacier expansion in the northern hemisphere (Denton and Karlen, 1973). The more recent of these is the historically documented "Little Ice Age" of northern Europe. Hester and Fraser's (1973) peat date of about 785 A.D. from 175 meters (574 ft) also appears to coincide with a period of warming documented by Denton and Karlen (1973).

Theoretically, this would identify high lake fluctuations with periods of cooler temperature, and low fluctuations with corresponding warm periods. In essence, Lake Michigan-Huron levels may provide an indication of late Holocene climates, and therefore should be studied in far greater detail than in the past.

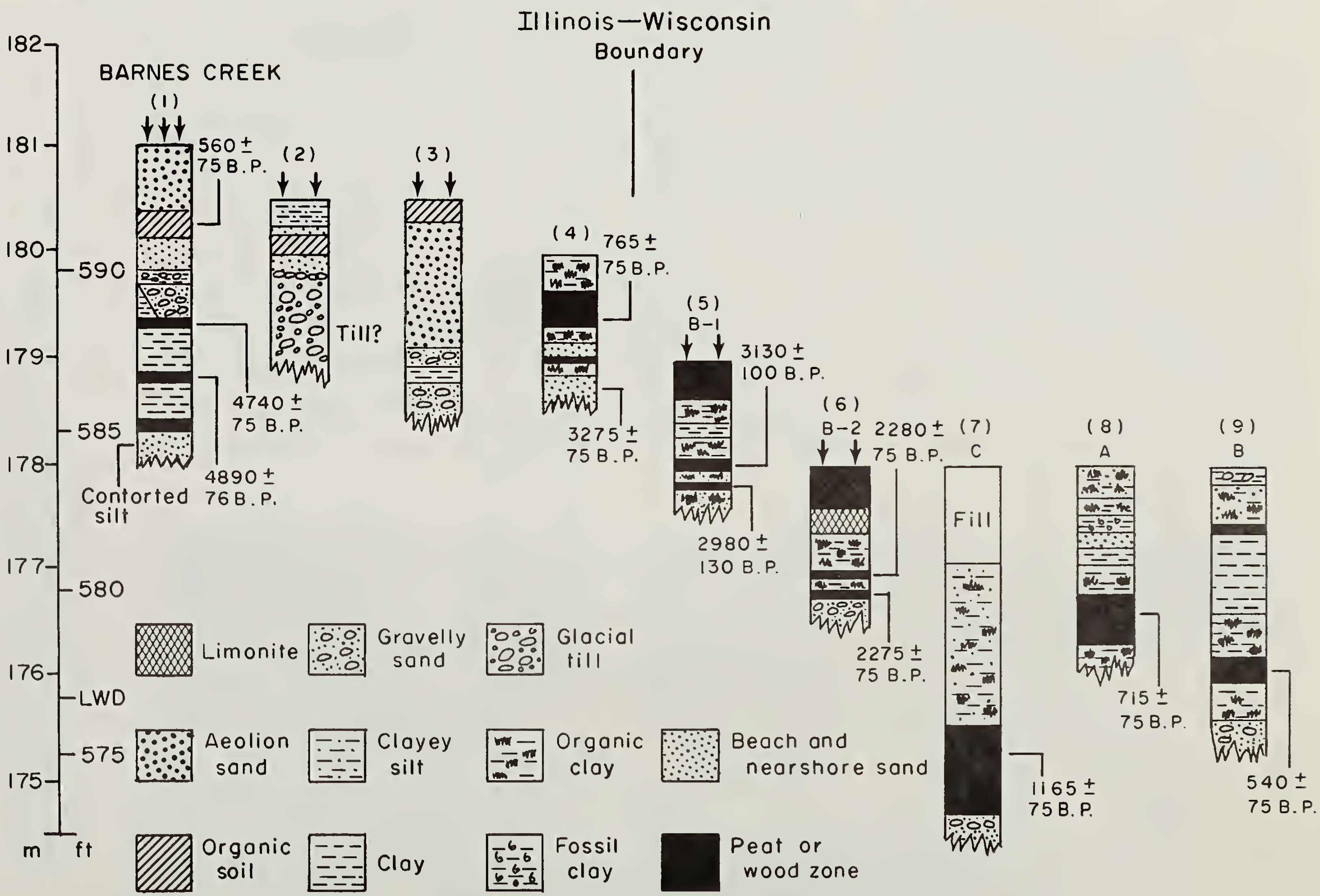

Fig. 15 - North-South cross section showing relationship of ^{14}C dated materials: Barnes Creek to Illinois Beach State Park. Refer to index map (p.29) for locations.

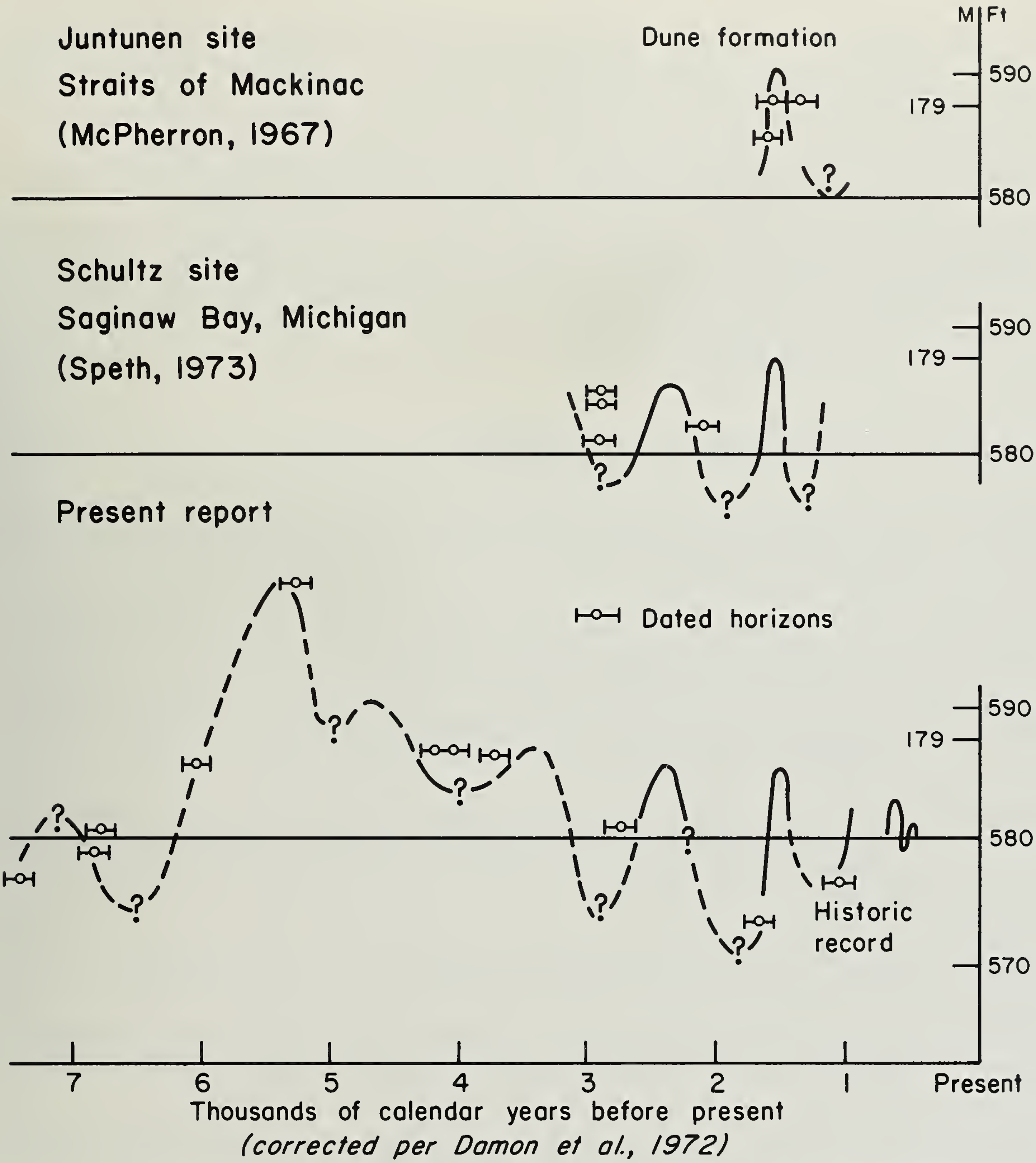

Fig. 16 - Fluctuations in late Holocene lake levels in southern Lake Michigan.

Perhaps more important to the potential solution of current environmental problems, fluctuations in lake level appear to indicate long-term trends that are not discernible in the historic record. Statistical data for deriving lakeshore design criteria are generally based on the record of 114 years of lake level changes. Holocene climatic influences on lake level are widely assumed to have been similar to those recorded during the past century and to have been superimposed on a downward trend of lake levels due to erosion of outlet channels (see, for example, Hough, 1958). The data shown here in a very preliminary way, however, indicate that serious flaws are inherent in any interpretations that do not take climatic factors into account in reconstructions of lake history or do not take prehistoric Holocene lake levels into account in predictions of future lake levels.

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